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THE SCIENTIFIC MONTHLY

JANUARY, 1924

HEREDITY OF EMBRYONIC CHARACTERS

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GENETICS has reached certain conclusions as to the nature of the germ-material that have an important bearing on the interpretation of the localization of the hereditary elements that influence development. Most of the genetic information has come from a study of the inheritance of the characters of adult animals and plants, but it is not without significance to find that the same conclusions can be derived from a study of the characters shown by embryos and larval forms. It would be out of place here to give the evidence for Mendel's theory of heredity, but its conclusions can be drawn upon and its principles illustrated by the inheritance of larval and embryonic characters. The most complete evidence comes from the caterpillars of the silkworm moth (Bombyx mori), especially from the work of two Japanese investigators, Toyama and Tanaka. Many races of silkworms are cultivated. The caterpillars show racial differences, especially in their color markings and in the color and shape of the cocoons. The heredity of more than a dozen different types of caterpillars and of several kinds of cocoons has been worked out. In addition, the color of the eggs and young embryos enclosed in the egg have furnished important evidence of "maternal inheritance," as has also the number of broods produced each year.

HEREDITY IN SILKWORMS

Toyama ('06) showed that when a race with striped caterpillars is crossed to a common pale race, all the resulting caterpillars are striped. If these are reared and the moths inbred there are produced 3 striped (1376) to 1 pale (417). The two races differ by one factor difference, and the results are like those found by Mendel in peas and explicable on the assumption that in the germ plasm

of the hybrid, the element for striped (that comes from one parent) separates from the element for pale (that comes in from the other parent). Half the eggs of such a hybrid contain the striped element and half that for pale.

Similarly in the hybrid male, half the sperm carry the element for striped and half for pale. Chance meeting of any egg by any sperm will give one pure striped to two hybrid striped to one pale, *i.e.*, 3 striped to one pale. Toyama also showed that when a race producing yellow cocoons is bred to a race with white cocoons, the offspring (F_1) produce yellow cocoons. If the F_1 moths are inbred, they produce three yellow cocoons to one white.

Toyama made crosses in which both larval and cocoon characters were involved. A pale race spinning yellow cocoons was bred to a striped race spinning white cocoons. The offspring were striped and produced yellow cocoons. When these were inbred they produced 9 striped, spinning yellow cocoons; to 3 striped, spinning white cocoons; to 3 pale, spinning yellow cocoons; to 1 pale, spinning white cocoons. This is the characteristic Mendelian ratio when two pairs of characters are present in a cross. If the members of each pair separate (segregate) in the hybrid, and if the separation of one pair is independent of that of the other pair, there should be produced in equal numbers four kinds of eggs and likewise the same four kinds of sperm, namely, striped yellow, striped white, pale yellow and pale white. If any one of these four kinds of eggs may be fertilized by any one of the four kinds of sperm there will be 16 possible combinations. If one remembers that striped dominates pale (when both are present) and yellow dominates white, these 16 combinations fall into four classes in the ratio of $9 : 3^a : 3^b : 1$ shown in the square below, where the dominant characters are underscored.

Eggs	Striped yellow	Striped white	Pale yellow	Pale white
Sperm Striped yellow	*Striped yellow* *Striped yellow* (9)	*Striped* white *Striped yellow* (9)	Pale *yellow* *Striped yellow* (9)	Pale white *Striped yellow* (9)
Striped white	*Striped yellow* *Striped* white (9)	*Striped* white *Striped* white (3^a)	Pale *yellow* *Striped* white (9)	Pale white *Striped* white (3^a)
Pale yellow	*Striped yellow* Pale *yellow* (9)	*Striped* white Pale *yellow* (9)	Pale *yellow* Pale *yellow* (3^b)	Pale white Pale *yellow* (3^b)
Pale white	*Striped yellow* Pale white (9)	*Striped* white Pale white (3^a)	Pale *yellow* Pale white (3^b)	Pale white Pale white (1)

Later ('12) Toyama discovered that there is a race that is re-

cessive for white cocoon color and another race that is dominant for white cocoon color. If the recessive is crossed to a race with yellow cocoons the offspring produce yellow cocoons. If these F_1's are inbred they give 3 yellow cocoons to 1 white. On the other hand if a dominant race is bred to a yellow-cocoon race the offspring produce white cocoons. If these F_1's are inbred the expectation is 3 white cocoons to 1 yellow.

Caterpillars that spin yellow cocoons have yellow colored blood; those that spin white cocoons have colorless blood. The color of the blood can be seen through the skin, particularly on the inside of the abdominal legs. The caterpillars in the last cases could be separated according to blood color as well as by the cocoon color. The outcome would be the same.

In addition to the kinds of caterpillars of the silkworm moth described above, there are several other characteristic types whose inheritance has been studied by Tanaka ('13, '14, '16). The factors of four of these (S, Z, M, N) were found to be dominant to four other types taken as allelomorphs (s, z, m, n), the latter when present alone producing a "plain coat." Later, Tanaka found that three of these (S, N, M) represent multiple allelomorphs; that is, each is a modification of the same factor; hence, only two of them can occur in the same animal at the same time (thus SN or SM or NM). Another factor Q (quail) is also said to be an allelomorph of S and M, hence of N also. The coloring of the larva homozygous (pure) for two of these factors (SS or QQ) is somewhat different from that of the combination of two of them (SQ for example). Tanaka also made the interesting discovery that the factor for yellow cocoon color (Y) is linked with each of these four allelomorphs. This means that when from one parent one of the factors (S, M or Q) enters a cross combined with yellow cocoon and from the other parent there enters another one of the caterpillar colors combined with white cocoon (two pairs of factors) there is not found in the second generation a 9 : 3 : 3 : 1 result, but a modification of the ratio due to the combination that went in together (SY on one side and My on the other) tending to remain together in the second generation, producing there a higher percentage of each combination that went in than expected in free assortment of the two pairs (S and M and Y and y). This phenomenon, known as linkage, is also often met with in crosses when adult characters are studied. It finds a rational explanation in the view that linked characters are carried in the same chromosome. Thus, in the above crosses, the factors for striped (S) and yellow cocoon (Y) character are carried in one chromosome and the character moricaud color (M) and white (y) in the corresponding chro-

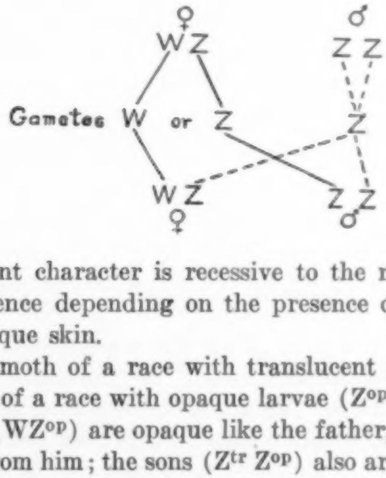
mosome of the other parent. These two chromosomes meet in the hybrid and separate when the germ-cells of the hybrid mature, giving two kinds of eggs (SY and My) and two kinds of sperm. If nothing further than this happened in the hybrid, then chance union of any egg with any sperm would give only the following combinations, 1 SYSY (striped yellow) : 2 SYMy (striped yellow) : 1 MyMy (moricaud white). The combinations that went in together would come out together, or, in other words, there would appear in F_2 only the two parental types in the ratio of 3 : 1. But the situation is not quite so simple as this, because recombinations of the characters that went in also appeared in the second generation, although, as stated above, not in the numbers expected (9 : 3 : 3 : 1) on free assortment of the two pairs. The explanation of this situation is also clear to-day for it has been shown that even when hereditary factors enter the cross in the same chromosome there is an exchange of factors in the hybrid between this chromosome and its mate. This is the familiar phenomena of crossing over. Since the interchange is not as free as when the pairs in question lie in different pairs of chromosomes the numerical results are correspondingly altered. Tanaka has shown in the female silkworm that no crossing over takes place (complete linkage) while, in the male, crossing over does occur to some extent (partial linkage).

Heredity in Other Moths and Butterflies

The inheritance of a few characters in other species of moths has also been studied. Goldschmidt ('21) records that the black type of caterpillar of the nun (Lymantria monacha) is dominant over the light type; the two characters behave as a single pair of Mendelian units. In an earlier account ('17) of crosses between different races of the gypsy moth (Lymantria dispar) a more complex situation is described by Goldschmidt. The different races of the moth spread over Europe and Asia have different races whose caterpillars show constant differences of pigmentation. The F_1 offspring are "about intermediate," the F_2 generation breaks up roughly into 3 light (medium) to 1 dark, if young stages of the caterpillars are alone considered. This was interpreted to mean that the degree of coloring in the different races is due to a series of multiple allelomorphic factors with different powers to produce pigment. As yet no sufficient data has been given to establish such a view. Goldschmidt concluded further that the factors in question are only different quantitative amounts of the same factor. Speculating further along these lines Goldschmidt assumed that by selection of the fluctuations of the factors (genes) in a plus or a minus direction a new mean could be established. The evidence

that he appealed to is quite insufficient to establish such a conclusion that has been shown not to be true in other cases where a more critical test has been applied. In addition to the difference between young larvae Goldschmidt also found that characteristic changes in the pigmentation of the caterpillars of different races take place as they pass from molt to molt. Light caterpillars remain light through the entire larval life in some races. In other races the caterpillars may become darker in some cases than in others. Medium light caterpillars of differing degrees may also change to dark. These differences were also ascribed to differences in "quantity" of the allelomorphic genes.[1]

In the adults of several animals (man, fish, flies and moths) there is a peculiar type of Mendelian heredity in which the character in successive generation follows the known distribution of those chromosomes connected with sex determination. There is also a case of this kind in the caterpillar of the silkworm moth where Tanaka ('22) found that the gene of one of the several types of "translucent" worms behaves in inheritance as though it were carried by one of the Z chromosomes. In this moth, as in others of this order, the female is supposedly heterozygous for the Z chromosome (WZ) and the male homozygous (ZZ). Thus—

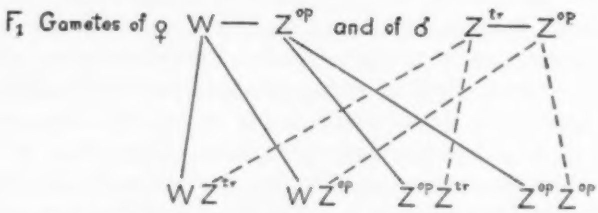


The translucent character is recessive to the normal or opaque skin—the difference depending on the presence of white granules in the more opaque skin.

In a female moth of a race with translucent larvae (WZ^{tr}) is mated to a male of a race with opaque larvae (Z^{op} Z^{op}), the daughter caterpillars (WZ^{op}) are opaque like the father, because they get this single Z^{op} from him; the sons (Z^{tr} Z^{op}) also are opaque, because the opaque character (Z^{op}) dominates the translucent character (Z^{tr}). If the moths from these F_1 caterpillars are inbred, half the

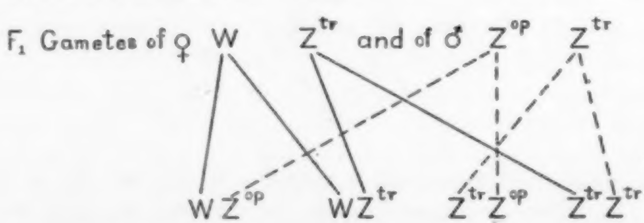
[1] In some wild races of the gypsy moth (*Lymantria dispar*) the caterpillars have a white streak along the dorsal midline; in other races the caterpillars have a broad black band along the back. When moths of these races are crossed the first generation caterpillars are black. When the F_1 moths are bred, the F_2 caterpillars are black or striped in the ratio of three black to one striped. This result was obtained by Klatt ('19) and confirmed by Baltzer ('20).

F_2 daughter caterpillars are translucent, half are opaque and all the F_2 sons are opaque. Thus:



The ratio is 1:1:2. It is apparent that the translucent character of the grandmother's race is transmitted to half the granddaughters and to none of the grandsons, although half of the grandsons carry one factor for translucent. This redistribution of the character conforms to expectation if the pair of genes involved is borne by the Z chromosomes of the two races.

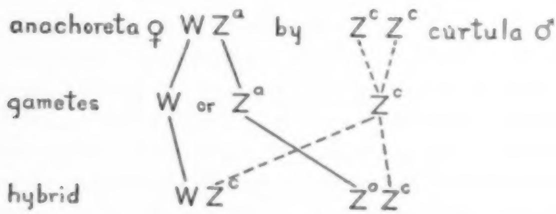
The converse experiment is equally instructive. If a female moth of a race with opaque larvae (WZ^{op}) is mated to a male of a race with translucent larvae (Z^{tr} Z^{tr}) the daughter caterpillars (WZ^{tr}) are translucent like their father, because they get their single Z^{tr} from him, and the sons (Z^{op} Z^{tr}) are opaque because of the dominance of the opaque character. If the moths from these F_1 caterpillars are now inbred half the daughter caterpillars are opaque, half are translucent, and half the male caterpillars are opaque, half are translucent. Thus:



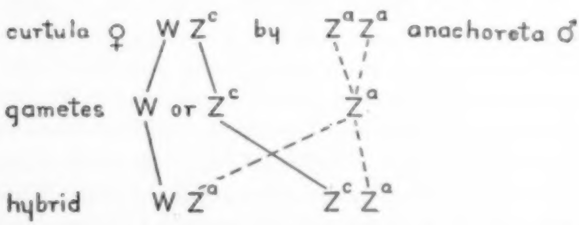
The ratio is I:I:I:I. Here the translucent character of the grandfather is transmitted to half of the granddaughters and to half of the grandsons. This redistribution of the character conforms again to expectation based on the behavior of the chromosomes.

Federley ('10) has described a case of sex-linked inheritance in a species-cross between the moths Pygaera anachoreta and P. curtula. The male and female caterpillars are alike in each species, but the caterpillars of one species are different from those of the other. When P. anachoreta is the mother and P. curtula the father, the male and the female hybrid caterpillars, after the first molt, are markedly different. The difference involves the form, color and

marking of the two kinds of individuals. The male hybrid caterpillars are closely similar to the caterpillars of the maternal race (anachoreta), while the hybrid female caterpillars resemble those of the paternal race (curtula). The explanation of this result is apparent if the character differences are due to genes carried in the Z-chromosomes; for the daughter gets her single Z-chromosome from her father, which she resembles, while the son gets one from each parent. If now the maternal Z^a (anachoreta) carries a gene (or genes) dominant to the gene (or genes) in the Z^c of the father (curtula) the son will resemble the mother because *ex hypothesi* she carries the dominant gene or genes.



The reciprocal cross bears out this interpretation. Thus, if P. anachoreta is the father and P. curtula the mother, all the offspring are alike. In this case the daughter again gets her single gene Z^a (dominant) from her father, while the son gets this dominant gene (Z^a) from his father, but also the recessive gene (Z^c) from his mother. Here, then, the male and female are both alike because the female carries only the dominant chromosome and the male carries both—the dominant one determining his character. Thus:



The analysis is further borne out by back-crossing the hybrid male to one or the other parental races. (It was not possible to make an F_1 cross, owing to the sterility of the female hybrid.) Federley succeeded in making such crosses. The results can not be explained by the ordinary extension of the formula, because, as Federley showed, the usual reduction of the chromosomes at the maturation division does not occur in the male hybrid. On the contrary, the two sets of chromosomes in the hybrid divide (twice) and as a result each sperm carries the diploid number—one set of

maternal and one set of paternal. When these sperm fertilize the eggs of a female of either original stock (curtula or anachoreta) the resulting offspring are triploid. Nevertheless, the relation of dominance and recessiveness assumed for the first generation crosses will explain the observed results, provided two doses of the recessive gene (two chromosomes carrying these genes) do not affect the dominance of the other genes (the single chromosomes carrying these genes).

The caterpillars of some moths have two (or more) color forms in the later stages. Weismann ('76) had speculated as to the interpretation of these types. Federley ('16) reared green and dark caterpillars and mated the moths that came from them; green female to green male, green female to dark male, dark female to green male and dark female to dark male. All the offspring were dark caterpillars. The results show that the difference is not genetic but environmental. The external factor that causes the change was not discovered. On the other hand Gerould ('21) has recently discovered a new color type of the common clover butterfly (Colias philodice) that behaves in its inheritance as a Mendelian recessive. This is a blue-green caterpillar that arose as a mutant of the normal yellow-green type. As in several other mutant characters in silkworm moths this one also is connected with an alteration in the color of the blood. In the normal caterpillar of this species, the color of the blood makes the caterpillar yellow-green. Correspondingly, the blood of the mutant is blue-green and shines through the skin after the first molt. Poulton pointed out ('85 '93) that in plant-eating caterpillars one green pigment in the blood is derived, with only a little change, from the chlorophyll of the food plant. It is the way then in which this change is affected by the genetic make-up of the mutant caterpillar that makes the color of the blood different from that of the normal caterpillar.[2]

In the group of moths and butterflies the sex chromosomes are represented by the formula WZ♀, ZZ♂. In other groups of insects another formulation holds, namely, XX♀ and XY♂. Here sex-linked inheritance is the same in principle as in moths, if the X's carry the sex factors. There are many adult characters of insects that show this form of sex-linked inheritance, and there is one case at least of a larval character that is inherited in the same way. In the vinegar fly there is a race which carries in one of its X chromosomes a Mendelian factor that produces a tumor in the larva,

[2] Hein ('23) has recently found three types of larvae of the meal worm (*Tenebrio malitor*) whose heredity shows that they are represented by three allelomorphic genes. Tower ('10) has shown that two larval types of the beetle *Leptinotarsa signaticollis* are represented in the germ material by two Mendelian genes.

and any larva that develops this tumor dies. The inheritance of the tumor may be illustrated by an example. All females of the stock carry one lethal factor in one of the X chromosomes, the other chromosome carries the normal partner (allelomorph) of this factor, and since the normal factor is dominant the female has not perished in the larval stage. She produces two kinds of eggs after the extrusion of one or the other X in the polar bodies. One X carries the lethal factor for the tumor, the other X its normal partner. If the eggs of such a female are fertilized by the sperm of a normal male—half of whose sperm are X bearing, and half are Y bearing—four possible kinds of embryos are expected. If the lethal bearing egg is fertilized by the X sperm, a daughter like the mother is produced; if the egg bearing the normal X is fertilized by an X sperm, a normal daughter is produced. The former is like the mother and transmits to half of her offspring the lethal factor, the other daughter is entirely normal and never transmits this tumor. If the lethal bearing egg is fertilized by the Y sperm, the sons, so produced, die because each contains only the maternal X with its fatal contribution. If the other kind of egg (bearing the normal X) is fertilized by a Y sperm, a normal son is produced that does not transmit the tumor to any of its descendants. The sex ratio has been changed, owing to the death of half the sons. The result is two daughters to one son.

Sex Formulas

In the sex formulas that have been here used, the WZ–ZZ and the XX–XY types, the W chromosomes in the former and the Y chromosomes in the latter have been ignored because experience has shown that they carry no factors that affect the Mendelian results. It is not to be inferred that even in these types no factors whatever are carried by the chromosomes. It has, in fact, recently been shown that the heredity of certain adult characters can only be explained on the view that such factors are carried by the Y chromosome and certain results of Goldschmidt on the gypsy moth have also been accounted for by him on the assumption that the W chromosome carries certain Mendelian factors.

Thus it has been shown by Schmidt ('20) and confirmed by Winge ('22, '23) that in the fish Lebistes a character peculiar to the male is carried by the Y chromosome, or at least the inheritance of this character is explained if its distribution is the same as that of the Y chromosome. Since the Y chromosome never gets into the female line it follows that the gene is never carried by the female and is transmitted only from father to son. It differs from the other type of sex-linked inheritance in one important respect, since

in the XX–XY type the X chromosome is shuffled back and forth between the sexes.

Aida ('22) has also found in another fish Amplocheilus that certain characters are carried by the Y chromosome and both Winge and Aida show that crossing-over may take place between the Y and X chromosome. It would seem to follow if the sex mechanism depends on a constant relation between the X or the Y and the other chromosomes that crossing over between X and Y would soon make them alike and destroy their relation in the sex scheme. This would be true only if more than one sex factor exists in the sex chromosomes; for, if only one pair is present it might be shuffled back and forth indifferently without affecting sex since then that one of the two sex chromosomes that contained the Y gene would, by definition, become Y. It can only be surmised, in case there is more than one sex factor in the sex chromosomes, that crossing over would occur only in that part of the X that does not contain the sex factors. The failure to cross over might possibly be due to difference in length of the X and Y, or to some other relation interfering with crossing over in one end or in some part. The suggestion may not seem so fanciful if it is recalled that in Ascaris it has been found that the X chromosomes are attached to another pair of chromosomes, that would correspond therefore to the supposititious X and Y of the fish.

Heredity of Down Color of Chicks

The inheritance of the color of the down of newly hatched chicks presents some unique problems. The color of the down may be and generally is quite different from that of the adult fowl, yet a certain down color is associated with definite adult colors. In some races of poultry the color of the down is uniform or nearly so, while in other races there is a characteristic down-pattern that bears no obvious relation to the pattern of the adult bird. The inheritance of these characters has not been fully worked out, but enough has already been done by Bateson ('02) Bateson and Punnett ('06) Goodale ('09) and Punnett ('23) to show that the inheritance is Mendelian. A few typical cases may be given.

The down of the white breeds, whether the white is the dominant or the recessive, is yellowish. If a dominant white breed is crossed to a colored breed the down of the F_1 chicks is white, although it may be slightly ticked, *i.e.*, it may show a few colored down-feathers. If a recessive white is crossed to a colored race the chicks have colored down. The actual color may depend on the color factors carried by the recessive white if these factors are dominant to those of the P_1 colored breed.

Buff races have buff chicks; black races have black chicks; blue adults come from blue chicks. Chicks of the Brown Leghorn race and of Game Bantams, both of which races approximate to the wild type, Gallus Bankiva, are brown-striped, *i.e.*, they have a brown pattern on a buff background. Barred birds, such as Plymouth Rocks, have black chicks that is less intense than that of black breeds and they have also a yellowish-gray patch on the back of the head. Other "barred" races, such as the Gold Pencilled Hamburgs, have striped chicks that are less conspicuously striped, however, than are Brown Leghorn chicks. The striped chicks of another "barred" race, the Campine, have very wide stripes, etc.

The inheritance of these characters of the chick follows closely the kind of inheritance shown by the adult bird of the races to which they belong, and, for the most part at least, may be supposed to be due to the effects of the same color factors acting on younger stages in which their effect may be outwardly quite different from the effects of the same factors on the adult birds. However, the work has not progressed sufficiently far as yet to exclude the possibility that there may also be specific factors that affect primarily the color of the chick and to a less extent that of the adult.

When certain races are crossed, more particularly where one race is silver and the other gold, the inheritance is sex-linked and follows the same rule as that for sex-linked characters of moths. The female has one Z chromosome and the male two Z's that carry these contrasted characters. The chicks show the same kind of inheritance as the adults, and since the difference is apparent at hatching it enables the breeder to pick out at once the F_1 males from the females if a suitable cross has been made. Thus, according to Punnett, when a Light Sussex hen is bred to a Brown Leghorn cock the silver male chicks are markedly different from the gold female chicks.

Maternal Inheritance

There is a form of heredity sometimes called maternal inheritance which, while Mendelian in principle, yet shows certain features that have an important bearing on embryonic phenomena. If the eggs of a species of sea urchin, or fish, whose cleavages have a certain tempo are fertilized by sperm of another species having a different tempo the cleavage of the egg is still that of the maternal race, *i.e.*, it shows no effect of the sperm. Since this is true of the reciprocal cross also, the results are evidently not due to the dominance of one type but due to a property of the egg itself —a property that has been impressed on the protoplasm, as other results show, by the maternal chromosomes. Expressed in another

way the result means that the chromosomes brought in by the sperm have not had time to change the condition of the egg's protoplasm already induced by its own chromosomes. That this is really the explanation is shown by rearing later generations from the eggs that have shown maternal inheritance in the first generation. While this has not been done in the case of the sea urchin or the fish it has been carried out in other forms. The best known case of this sort is that of the silkworm moth where Toyama has shown that the color of an embryonic egg-coat, the chorion, follows the scheme of maternal inheritance. More recently Uda ('23) has published facts that may be interpreted to mean that the embryonic membrane, the serosa, that Toyama supposed also to be inherited as a maternal character is not inherited in this way.

One of the most interesting cases of maternal inheritance shown by silkworms relates to the number of broods per year. In some races there is only one generation a year (univoltine), in other races there are two generations. When such races as these are crossed the hatching of the egg is a function of the maternal race. The simplest explanation of this result is that it is due, in all likelihood, to some peculiarity of the egg-coat.

A striking case of maternal inheritance has recently come to light that bids fair to explain one of the outstanding puzzles of heredity.

In some species of snails, the shell and its contained viscera are coiled in a right spiral (dextral) in others in a left spiral (sinistral). It was shown by Crampton and by Kofoid ('94) that these two types can be distinguished as early as the second cleavage, and perhaps even at the first, by the form of the cleavage pattern—one is a mirror figure of the other. It was known from the observations of Mayor ('02) and of Crampton ('16) on Partula, and has been confirmed by the recent work of Boycott and Diver ('23) on Lymnaea, that all the offspring of a given brood are dextral or else sinistral. It has also been shown that some sinistral mothers produce only sinistral broods and that other sinistral mothers produce dextral broods. Conversely, some dextral mothers may produce only sinistral broods and other dextral mothers may produce dextral broods. These facts were very puzzling from a genetic standpoint, and there was no satisfactory explanation at hand. The recent extensive experiments of Boycott and Diver have supplied data which Sturtevant ('23) has shown can be interpreted, if the character of the cleavage (hence the character of the adult) is impressed on the egg by its genetic make-up before the maturation divisions have occurred. An example will serve to show the principle involved.

Suppose, as the evidence indicates, there is a dominant dextral

and a recessive sinistral factor carried by a given pair of chromosomes. A self-fertilizing dextral snail that is heterozygous for these factors (Ll) produces after maturation two kinds of eggs L and l. Similarly, there will be two kinds of sperm; namely, L and l. Self-fertilization will give three genetic types of offspring—LL, Ll and ll; but all these individuals will be dextral because the cleavage pattern has been already determined in the egg by the dominant factor L before the polar bodies were given off. Of these three types the first two LL and Ll will produce only dextral offspring, but the other type, ll, that has also a dextral shell will produce only sinistral offspring. Since these snails may also cross-fertilize, provided dextral mates to dextral, and sinistral to sinistral, it is possible for the dextral female (arising as above) with the genetic constitution ll to mate with a dextral with the composition LL. All the offspring of such a somatically dextral female will be sinistral, since the undivided egg was under the influence of the two recessive genes (ll). These sinistral snails (Ll) in turn will produce only dextral offspring because the dominant factor L in the egg determines the type of cleavage of the eggs. It is evident, therefore, that dextrals of certain origins will produce only sinistral broods and sinistral of certain origins dextral broods. The heredity is Mendelian, but the appearance of the character is delayed for a generation. The result is unique, because the symmetry of the individual is determined not by its own genetic constitution but by that of the unreduced egg from which it arose.

POLITICS AND SCIENCE

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Is there a science of politics or indeed of any of the social studies? If so, how may the field of investigation be defined and differentiated, and what are the postulates and methods and some of the laws or principles which have been established?

The term "political science" is an assertion or claim that there is such a science; but at the same time the use of the word "science" indicates at the outset that there is a special need for asserting that it is a science, which does not seem to exist in the case of other sciences, such as astronomy, physics, chemistry, geology, botany and zoology. Moreover, other terms, such as political philosophy and political theory, have also been used for studies in political institutions, which indicate that at least some students in this field distinguish their work from that of science.

It is true that the standard dictionaries define "politics" as both an art and a science; and one explanation for the term "political science" may be found in the general use of the term politics for the art or practice of government. Curiously, no one seems to have suggested the term "politology" for the science of politics, if such there be.

The existence of any science of politics has, however, been openly disputed by writers of standing. More generally, workers in the physical and biological sciences have appropriated the term science as applying only to their own group of studies, ignoring not only politics, but often also all the social studies. In some cases, where a comprehensive analysis and classification of the sciences has been made, there has been a grudging recognition of "sociology" as a prospective science in its early beginnings, with politics and economics noted as branches or applications of such a future science.

Thus Comte, in his "Positive Philosophy," denied the claim of politics to be ranked as a science, on the ground that: (1) there was no consensus of opinion among experts as to its methods, principles and conclusions; (2) it lacked continuity and development; and (3) it lacked the elements which constitute a basis of prevision.[1] So, too, John Stuart Mill wrote (in his "System of Logic," 1843):

[1] "Positive Philosophy" (1830–42). Eng. trans. by Martineau, ed. of 1893, Vol. II, Ch. 3.

It is accordingly but of yesterday that the concept of a political or social science has existed anywhere but in the mind of here and there an isolated thinker, generally very ill-prepared for the realization.

And Buckle, in his "History of Civilization" (1857), declared that "in the present state of knowledge, politics, so far from being a science, is one of the most backward of all the arts."[2]

Professor Sheldon Amos, author of one of the earliest works on "The Science of Politics," noted that objection to the study of politics as a science came from two radically opposing types of mind. Speculative minds "are discontented with the notion of a so-called science of politics" because of the complexity of the subject-matter, and the intrusion, at all points, of such seemingly incalculable factors as the will and passions of mankind. Practical statesmen, again, immersed in actual business, and oppressed by the ever-recurring presence of new emergencies, almost resent the notion of applying the comprehensive principles of science, and still more the conjectural use of foresight, in respect of subjects which, for them, are in ceaseless flux, and can, at best, only be safely and wisely handled "by momentarily adjusted contrivances." . . . "The aggregate result is that politics floats in the public mind either as a mere field for ingenious chicane or as a boundless waste for the evolution of scholastic phantasy."[3]

The prevailing attitude of those in the more clearly recognized physical and biological sciences may be indicated by the action of two leading organizations of such scientists in the United States. The American Association for the Advancement of Science, with an elaborate organization of sections for the various physical and biological studies, has but a single section on social and economic science, with no provision for students of politics. The National Research Council, whose name and authorized purposes indicates that it proposed to deal with all fields of research investigations, has been composed of physical and biological scientists and has announced that its work will be limited to such sciences, with no provision for research in the social studies.

The views of present-day physical and biological scientists are more definitely set forth in two recent brief but comprehensive analyses of the field of science. Professor J. A. Thomson, in his "Introduction to Science" (1911) lists "sociology" as one of the great fundamental sciences, of which politics, civics and economics

[2] Vol. I, p. 361.

[3] "The Science of Politics" (1883), p. 2. *Cf. The Times Literary Supplement*, August 31, 1922: "The art of the statesman is concerned with the possible, the practicable, the gradual. It has nothing to do with mathematical certainties and universalities, and still less with Utopias and Paradises."

are but applications; and of sociology he states that it "is still a very young science."[4] Professor du Sablon, in his "L'Unité de la Science" (1919) gives one chapter of 17 pages (out of 280) to the "moral sciences," including ethics and social studies, and concludes that "the moral sciences are much less advanced than the biological or the physical sciences. We see them still in the descriptive period, where the phenomena are observed without always knowing their causes and without being able to establish their laws."[5]

Before considering what may be said of politics as a science on behalf of those who have given serious attention to the study of this subject, we may turn to recognized scientists for a definition of science, and a statement of its distinctive methods, by which the claims of politics may be tested.

In his "Grammar of Science," Karl Pearson states that "the classification of facts, the recognition of their sequence and relative significance is the function of science." Professor J. A. Thomson defines science as "criticised, systematized and generalized knowledge." He also summarizes his discussion of scientific method in these words:

> The first step in scientific procedure is to collect data, and all science begins with measurement. The second step is the arrangement and classification of facts. Auxiliary to this and to formulation is the process of analysis or reduction to simpler terms . . . it is often necessary to try one hypothesis after another. An important step in the procedure is the carrying out of test experiments. The final result is a general formula or law of Nature, or more frequently the inclusion of a new set of facts within an old law.[6]

Professor du Sablon carries the scientific process beyond Thomson's final step. Concluding his study on the unity of the sciences, he states:

> All the sciences develop in the same way. The point of departure is furnished by the direct observation of nature; the induction leads to a series of laws which are only the generalized expression of the phenomena; finally, experimental science is encompassed by a theory in which the laws and phenomena are deduced from certain principles laid down *a priori*. The methods successively employed are then: experience, induction, deduction.

[4] In Home University Library, Ch. 4, p. 107.

[5] P. 270.

[6] "Introduction to Science," pp. 79–80. In the more recent "Outline of Science" (Vol. 4, p. 1169) Professor Thomson states that: "Science includes all knowledge, communicable and verifiable, which is reached by methodical observation and experiment, and admits of concise, consistent and connected formulation." The methods of science, he adds, are: first, to get the facts by observation; second, accurate registration of the facts; third, arranging the data in workable form; fourth, finding a law or formula for uniformities.

If the definitions given above are accepted, it can hardly be denied that there have been from early times a scientific study of politics by the systematic analysis and classification of facts leading to generalizations. There have also been theoretical, speculative and imaginative writers on political subjects, from Plato in his "Republic," to More's "Utopia" and Bellamy's "Looking Backward," whose works have not been closely related to the systematic study of the facts of political experience, and can not well be claimed as scientific. But the scientific work of Aristotle in the field of politics was more thorough than in the natural sciences, and he considered politics as the "master science."[7] With him may be classed other less important writers of ancient times, such as Polybius and Cicero; and in later times there are such outstanding names as Machiavelli (who is said to have "founded the science of politics for the modern world by concentrating thought upon the fundamental principles"),[8] Bodin, Hobbes, Montesquieu and Madison.

It may, indeed, be said that at the end of the eighteenth century the science of politics was further advanced than the physical and biological sciences. But, with the marvelous development of these other sciences in the nineteenth century, politics and other social studies seem to have at least relatively lost ground; and it is in view of the recent achievement of the natural sciences that the social studies have come to be considered as in a backward stage, if they are to be admitted as having at all the status of a science as the term is used at the present time.

Nevertheless, it may be shown that the scientific study of politics, and also of other social studies, has made substantial progress during the past century. In the middle nineteenth century, Comte, Buckle and John Stuart Mill (whose deprecatory statements about the status of politics as a science have been noted) each made notable contributions. Of the many later workers in this field, mention may be made of such important figures as Sir George Cornwall Lewis, Henry Sidgwick and James Bryce (in Great Britain), Bluntschli and Jellinek (in Germany), de Tocqueville (in France), and (in the United States) Francis Lieber, Theodore Woolsey, John W. Burgess, Jesse Macy, W. W. Willoughby and F. J. Goodnow.

[7] *Cf.* E. Barker, "The Political Thought of Plato and Aristotle," pp. 10, 237–241.

[8] Encyclopedia Britannica (9th ed.), XV, 150. Bodin is said to have given system to the modern science of politics by his definition of sovereignty. David Hume in an essay entitled, "That politics may be reduced to a science," asserted that: "So great is the force of laws and of particular forms of government, and so little dependence have they on the humours and tempers of men, that consequences almost as general and certain may sometimes be deduced from them as any which the mathematical sciences will afford us."

The mention of such writers on political institutions and their works is of service, as was noted by Professor Amos, forty years ago, "first, as substantiating the truth that there is a veritable science of politics, and then as illustrating the special difficulties which the cultivation of that science has to contend with." The same writer, after analyzing the objections and obstacles to the development of a complete science of politics, also noted the indications that the study of politics was "being placed on a platform of far higher scientific exactness than ever before" and came to the conclusion that "the scientific method in politics, as elsewhere, is slowly and surely getting the better of the empiric."[9]

About the same time Sir Frederic Pollock, in his lectures on the "History of the science of politics," maintained that "there is a science of politics in the same sense, and to the same, or about the same, extent, as there is a science of morals." He added, further, that "political science must and does exist, if it were only for the refutation of absurd political theories and projects."[10]

That a considerable advance in the study of politics has been made since these modest statements were made may be indicated by the views, still conservatively expressed, of one who will be recognized as a leading figure in that advance, and whose work in this field may well be compared to that of Darwin in biology. In his annual address as president of the American Political Science Association in 1908, the late James Bryce undertook to say of political science, "What sort of a science is it?" Granting that it is not an exact science, such as mathematics, physics or mechanics, and admitting that the data of politics can not be weighed with the precision of natural phenomena, he took the position that

> in calling politics a science we mean . . . that there is a constancy and uniformity in the tendencies of human nature which enables us to regard the acts of men at one time as due to the same causes which have governed their acts at previous times. Acts can be grouped and connected, can be arranged and studied, as being the results of the same generally operative tendencies.

He also maintained that "it is not a deductive science any more than it is a branch of speculative philosophy," but was found on the systematic analysis of historical facts. Further, he added:

> It is an experimental science, for though it can not try experiments it can study them and note results. It is a progressive science, for every year's experience adds not only to our materials but to our comprehension of the laws that govern human society.[11]

[9] "The Science of Politics," pp. 17–21.

[10] Pp. 2–4.

[11] *American Political Science Review*, III, 1–19 (1909).

The status of politics as a science may be further examined by considering its postulates and methods of procedure, and noting how far they correspond to or differ from those of other sciences.

As to postulates, the student of politics, as of the physical sciences, accepts as established for his purposes by common experience the existence of a world of conscious persons and of things; but with considerable difference of emphasis and importance for his investigations.[12] The nature and characteristics of impersonal things, whether animate or inanimate, is not a direct object of inquiry in politics; in such matters the established results of other sciences are accepted, though the study of groups of animals is of direct interest to the investigation of social institutions, and some analysis and comparisons can be made to political institutions.

On the other hand, in politics and all the social studies, the nature and characteristics of human persons are of greater importance than in the physical and biological sciences, except in psychology, if that is included with the latter group. In the social studies, as in all science, the student and investigator is a person whose characteristics have much to do with his inquiries and their results; and the existence of other persons making similar inquiries is recognized and accepted. But, in addition, the object of inquiry is also the great body of human persons, including the investigator and his colleagues, with special reference to their actions in connection with their fellows which differentiate them from impersonal objects.

Politics, as distinguished from other social studies, deals with the life of men as organized under government and law, in what is known as the state. It includes a study of the organization and the activities of states, and of the principles and ideals which underlie political organization and activities. It considers the problems of adjusting political authority to individual liberty, the relations among men which are controlled by the state and the relations of men to the state. It also deals with the distribution of governing power among the several agencies by which the actions of the state are determined, expressed and executed, and with the political problems of international life. As a science, it aims to furnish a basis of accurate information and intelligent opinion, in place of emotions and prejudices, for forming judgments in public affairs; and it seeks to develop a sense of the rights and responsibilities of citizens and an understanding of the significance of law. As its distinctive contribution to the social studies, it lays emphasis on

[12] These postulates may be contrasted with those of President Woolsey in his treatise on "Political Science," published in 1878. "We assume the personality and responsibility of man as a free moral being. We assume also a moral order of the world. . . . We discard the greatest happiness theory. . . . We hold also, most firmly, to a system of final causes."

law as a means of social control and on governmental action for the promotion of general welfare.

The methodology of political science has been discussed by a number of writers. Comte considered that there were three principal methods for the scientific study of social phenomena—observation, experiment and comparison. These are well-recognized scientific methods, and with these may be considered the employment of statistical data as a means of measurement. To these, there may be added the method of subjective introspection, and, as in all scientific inquiries, the process of reasoning from the data forms an important stage in leading to conclusions.

Comte noted further the historical method in social investigation, to be applied only in dealing with the most complex phenomena. But this term seems to belong to another category from those noted above—including juristic, biological, psychological and sociological. These terms, however, do not indicate so much methods of investigation as points of view from which political and social institutions may be studied, suggesting the application of methods employed in these other fields of inquiry.

Still other terms are particular aspects or subdivisions of a general procedure rather than distinct methods.

Those who undertake the study of politics as a science, as distinguished from those who are mainly concerned with matters of theory and speculation, take for their starting point the observation and examination of political phenomena. It must be recognized, however, that the extent to which any single investigator can make direct personal observations of the widely scattered political phenomena is closely limited. It is a very exceptional case where one man can cover even a considerable fraction of the ground traversed by James Bryce, travelling for threescore years in all parts of the world. Even Mr. Bryce secured much of his data from others. Most students must depend even more largely on official records and on the reports of other direct observers; and allowances must often be made for the aberrations and refractions of these telescopes and microscopes of the political investigator. So, too, the student in other scientific fields does and must depend on and accept to a large degree the results of others. The trained observer can recognize and segregate doubtful items, and base his further study on acceptable data. But better work could be done, if larger provision was made for more direct observation by men of scientific training.

The place of experiment in political science has been much discussed and its validity has been openly questioned. Sir George Cornwall Lewis held that:

If by an experimental science, we mean a science which admits of scientific experiments, of *experimenta lucifera,* then politics is not an experimental science; but if we mean a science founded on observation and experience, politics is an experimental science.[13] . . . We can not do in politics what the experimenter does in chemistry. . . . He may isolate the phenomenon with which he deals and expose it to certain selected influences, leaving the surrounding medium unchanged. But if the political scientist wishes to experiment with democracy, for instance, he can not select a state at will, introduce his democracy and wait for determinate results. He will find himself powerless to exclude extraneous influences, such, for example, as panics, commercial crises, insurrections or other happenings, which might destroy the results of the experiment.

John Stuart Mill, in his *Logic,* also considered real experiments in politics to be impossible. And Sheldon Amos, in his "Science of Politics," referring to Mill and emphasizing the importance of repetitions with exactly estimated variations for a true experiment, urged that on account of human personality and the influence of the past on the future, no combination of circumstances can be repeated once, let alone often.[14]

It must be recognized, as John Adams observed, that "a political experiment can not be made in a laboratory, nor determined in a few hours." But experiments may be made outside of a laboratory, and while the phenomena of politics may not be so thoroughly isolated nor subject to as large a measure of control as in the laboratory, it remains true, as was noted by William James, that "non-isolable elements may be discriminated provided their concomitants change."

Indeed, it may be said that governments are continually trying experiments on the community. Every new law, every new institution, every new policy is to some degree experimental.[15] Most of them are modified to meet the needs indicated by experience; and some are quickly repealed or abandoned after a short trial. Bryce, in his "American Commonwealth," pointed out as one of the merits of our federal system of government that "it enables a people to try experiments in legislation and administration which could not be tried in a large centralized country."[16]

But while novel schemes are frequently tried in modern governments, the observation and critical examination of the results are too often inadequately carried on, and the value of the experiment

[13] "Methods of Observation and Reasoning in Politics," I, 178.

[14] Amos, "Science of Politics," p. 113. Bryce, in "Modern Democracies" (Ch. 2), notes that: "Experiments in physics can be tried over and over again until a conclusive result is reached, but that which we call an experiment in politics can never be repeated because the conditions can never be exactly reproduced"; as Heraclitus says, "one can not step twice in the same river."

[15] Garner, "Introduction to Political Science," p. 23.

[16] Third Ed., Vol. I, Ch. 30, p. 353.

may be largely or wholly lost. The direct primary has been introduced in many states in this country, and legislation by initiative petition and referendum in a number. Both of these devices have been in use for a considerable period of years. Both are still eagerly supported and bitterly denounced. But there has been as yet no comprehensive attempt at a scientific examination of the results; and the general opinion is affected largely by a few particular instances which happen to attract attention. This, however, is not because students of politics are not able to undertake such investigations; but to the lack of the means for scientific research on such political problems to the same extent as they are furnished in the case of an expedition to Crocker land or the South Pole or studies in astrophysics.

The limitations on political experiments do not, however, prevent the scientific study of politics. In the most exact of the physical sciences, that of astronomy, experiments are impossible; and in geology, the collection of data in field studies is less subject to control than in the case of political phenomena.

The method of comparison comprehends a variety of processes, such as the arrangement of data, its classification, coordination and elimination.[17] It includes what is sometimes referred to as a distinct "historical" method, for this involves a comparison of institutions and conditions at different periods, which is as important for the student of politics, as is the life history of a plant or animal to the biologist. Such historical studies also serve to emphasize the elements of continuity and development in political institutions. As was said by Professor Seely, "History without politics has no fruit. Politics without history has no root." Or, as stated by a French writer (M. Deslandres), "History is the solid element without which political science would only be fragile and hazardous."[18]

But the comparative method in the study of politics embraces more than the historical study of one political system. It involves a comprehensive examination of different systems, in different countries, and under different conditions. By comparing points of difference and agreement, a basis can be found for comparing the results of varying factors; though the complex plurality of factors add to the difficulties of tracing the results of any one.

To quote Bryce again:

> That which entitles it (the comparative method) to be called scientific is that it reaches general conclusions by tracing similar results to similar causes, eliminating those disturbing influences, which, present in one country and absent in another, make the results in the examined cases different in some points while similar in others.[19]

17 Garner, *op. cit.*, p. 22.

18 Quoted by Garner, *op. cit.*, p. 29.

19 "Modern Democracies," Ch. 2.

There has been a marked development during the recent decades in the scope and character of data and the intensity of inquiries as the basis for the study of politics. Until after the middle of the nineteenth century most of the writers on politics gave little attention to the detailed investigation of data, and their writings were largely legalistic deductions based on *a priori* generalizations. Then attention was given to historical records and the comparison of official documents and legal institutions. In the latter part of the century Mr. Bryce led the way to a much broader scope of personal observation, including the examination of legislative procedure, political parties and other extra-legal practices and customs, in what President Lowell has called the physiology of politics.

Developments may also be noted in the attention given to various factors affecting political conditions and to the influence of analogies from other fields of study. Thus, for a time environmental conditions occupied the foreground, with varying emphasis on physical and geographical, economic and social conditions. With the progress of biology more consideration was given to the influence of heredity, racial characteristics, the organic view of political and social organization and the idea of progressive evolution.

Nevertheless, until the end of the last century most students of political problems obviously avoided the application of standards of quantitative measurement in their work; and thus seemed to acknowledge that their studies lacked what has been said to be the first essential of scientific procedure. As already noted, Lord Bryce frankly stated his belief that political data could not be measured with precision, and that politics, therefore, could not be considered an exact science. His own work shows the influence of this view, in his avoidance of statistical and other numerical data; though this may have been at least partly due to the literary character of his writings, which appealed to a wide audience, and avoided the technical analysis of the professional scholar.

It may be recognized that much of the statistical data used in discussions of political and social subjects is far from complete and is sometimes based on rough estimates; and also that many political phenomena have not, at least as yet, been reduced to precise measurement, though in some directions the psychologists seem to be making some advance in this matter.

It can be urged, however, that there is a large body of reliable numerical data as to political and governmental action available for scientific analysis, and that much more could readily be secured in the scattered records of public offices with much less difficulty and expense than that which is met in securing their primary data by students of the physical and biological sciences. As illustrations

may be cited election statistics, the records of the financial transactions and the activities of public officials, and the proceedings of legislative bodies.

The Belgian statistician Quetelet (1796–1874) made the first important use of statistical methods in the study of social phenomena, by applications of the theory of probability, in "Sur l'homme et le development de ses facultés" (1835). More recently President Lowell has shown how effective and scientific use can be made of political statistics in his analyses of voting in legislative assemblies (in his "Government of England"), and of popular voting on constitutional and legislative measures (in his "Public Opinion and Popular Government").

Within the last twenty years, there has been a considerable development of more systematically organized research work in politics, and other social studies, based largely on statistical and other measurable data. On a small scale, some work of this kind has been done by legislative and municipal reference bureaus; and more important studies have been made by some of the numerous temporary commissions and permanent administrative agencies, on such subjects as education, taxation and administrative organization. There have also been organized a considerable number of bureaus of governmental research, supported by private funds, for the intensive study of governmental conditions. Much of the work of these bureaus has been done by engineers and accountants, making use of statistical data. Applications of statistics in other fields, such as anthropology and psychology, have also dealt with problems of political interest.

But what has been done in these directions has barely scratched the surface, and the possible scope of such studies is almost unlimited, if resources can be secured for collecting the data and for its critical examination by competent students.

In one respect the study of politics and of the other social sciences can hardly avoid recognizing a factor which is not so clearly recognized in the physical and biological sciences; and this makes possible, if not necessary, one method or process not openly utilized in these other sciences. The study of political and social action involves some ideas as to the character of what is called human nature, and more particularly as to the characteristics of the human mind. But this is, of course, the field of psychology, and with reference to collective groups more especially of social psychology. The political scientist must, therefore, have some notion as to psychological principles, either by accepting those of the psychologists in so far as these are established, or undertaking inquiries in this field for himself.

Such a study of human nature or the human mind, as related to political and social action, might be undertaken as an objective study, as by the behavioristic psychologists. But inasmuch as the political and social investigator is himself one of the human beings whose conduct is being considered, it is possible to make, and indeed difficult to avoid making, some judgment as to the mental processes affecting human conduct by subjective consideration of what at least seems to go on in the investigator's own mind. And until the behavioristic psychologists can furnish a reasonably adequate explanation of mental processes on an objective basis, the method of subjective introspection not only can but probably must be recognized by the student of politics as a factor in reaching his conclusions.

It may be admitted that this method is as yet less accurate and reliable in securing uniform or closely similar results than the observations and laboratory experiments of physics and chemistry, though the latter are coming to be more clearly recognized as close approximations rather than absolutely exact formulations. But, if employed, not merely in a haphazard way by isolated individuals, but in a systematic and cooperative manner by a considerable number of careful students, as a means of interpreting the observed action of political and social groups, it may well be accepted as furnishing a basis for at least tentative opinions on questions not capable of determination merely by observation and comparison.

Such cooperative and systematic use of the method of subjective introspection can not be said to have developed to any large extent, and for this reason, the casual reflection and judgment of individuals still lack a good deal as a satisfactory basis for scientific judgments. Even such an experienced and careful student of politics as Lord Bryce, in postulating what seems to be a substantial uniformity of human nature,[20] has made an assumption, which (while simplifying the problem) is probably inadequate. There is need for further study as to the stability and changeability of human nature. Important recent studies in this direction are those of Graham Wallas in his "Human Nature and Politics" and "The Great Society," the recent analysis of the processes of formulating "Public Opinion," by Walter Lippmann and Dewey's "Human Nature and Conduct."

[20] " . . . there is in the phenomena of human society one "Constant," one element or factor which is practically always the same, and, therefore, the basis of practically all the so-called "Social Sciences." This is Human Nature itself. . . . Human nature is the basic and ever-present element in the endless flux of social and political phenomena which enables general principles to be determined. . . . Politics accordingly has its roots in Psychology." "Modern Democracies," Ch. 2.

The varying results and the slight development of a systematic application of subjective analysis may explain in part the retardation in the development of politics and other social studies on a scientific basis. But it may be submitted that the recognized and systematic use of this additional process should add rather than detract from the scientific character of these studies. It may also be suggested that, even in the physical and biological sciences, the mental reactions of the investigators are important factors in reaching their results; and the analysis of their methods is inadequate until such factors are recognized and considered.[21]

The scientific study of politics, as of other sciences, also requires the process of reasoning. As stated by Professor Seeley, "We must think, reason, generalize, define and distinguish; we must also collect, authenticate and investigate. If we neglect the first process, we shall accumulate facts to little purpose, because we shall have no test to distinguish facts which are important from those which are unimportant; and of course if we neglect the second process, our reasonings will be baseless and we shall but weave scholastic cobwebs."[22]

There have been, as already noted, many writers on political subjects, whose reasoning has been speculative and theoretical, though even some of these may have been influenced by observation and comparison. Other more scientific students of politics, whose discussions are related to the facts of observation, have differed as to their use of different methods of reasoning; and have been classified in different groups or schools.

One group of writers, both in Europe and America, have followed what has been called the juristic method. Of English writers, John Austin is notable for his application of deductive legal analysis to political problems. According to Professor Jellinek, formerly of Strasbourg University, this method aims to "determine the contents of the rules of public law and to deduce from them the conclusions to which they lead." In America, students and writers on constitutional and other branches of public law base their work largely on judicial opinions and legal reasoning, and some at least have applied these methods to the consideration of political problems not clearly legal in character.

But legal and judicial reasoning is not all of one type. Professor John H. Gray, of the Harvard Law School, writes in his lectures on the "Nature and science of the law," that there have been three leading methods of approaching the study of jurisprudence

[21] Professor J. A. Thomson states that: "Science is not so objective as it is sometimes supposed; we can no more escape from anthropomorphism than from our shadow." "The Outline of Science," IV, 1168.

[22] "Introduction to Political Science," p. 19.

—the analytical, the historical and the deontological, and that some writers have used all three methods. Dean Roscoe Pound, in his recent "Introduction to the Philosophy of Law," after tracing the methods of legal thinking from early times—Greek, Roman, the scholastic jurists of later medieval times, and the natural law writers—notes in the nineteenth century four well-marked types: First, an American variation of natural law, as deduced from American institutions; second, a metaphysical-historical method developed first in continental Europe; third, the utilitarian-analytic method, in England and the United States; and fourth, at the end of the century, a method of positivist sociological thinking, with a revival of natural law in terms of social utility.

Still another view of legal reasoning is presented in an article recently published, holding that lawyers and judges have been applying the methods of behavioristic psychology.[23]

All these methods of juristic reasoning are also applicable to the study of political institutions. They may be considered as variations and combinations of the primary classification into deductive and inductive logic; and the decided tendency of the recent scientific students of politics is away from the exclusively deductive logic of the analytic and deontological (or ethical) writers, towards the joint use of the inductive and deductive methods, characteristic of the historical and still more of the sociological writers, as it is also of the physical and biological sciences.

Political writers of to-day not only supplement the purely deductive logic of the analytical jurists, but they clearly go beyond the study of legal institutions and forms, to include the consideration of extra legal factors, social and political, which underlie the formal legal organization of the government and control many of its actions.

Students of political conditions also illustrate and reflect the varying tendencies of philosophical discussion, and in some cases have anticipated changes in their methods. The juristic analysts of law and politics may be compared to the absolute monists of philosophy, in seeking a single, indivisible principle behind the complex phenomena. But there are also political pluralists and pragmatists; and in recent years these have been active in their interpretations and in proposing new solutions of political problems. So, too, the doctrine of the relativity of political institutions to varying conditions has tended to replace the former views of absolute standards for all times and peoples.

In the discussion of political and other social problems, there are greater difficulties in the use of language than in the physical and

[23] *Journal of the American Bar Association,* Dec., 1922.

biological sciences.[24] The terms of politics and social affairs are not of a specialized technical character; but are, for the most part, words in common use, with vague and varying shades of meaning. This variety is further increased by the popular and literary discussion of such problems, with little effort at, and even less success in, the accurate presentation of the data and the conclusions. Moreover, a considerable number of terms employed have acquired emotional and ethical connotations, which arouse feelings of approval and disapproval, and retard efforts at an unimpassioned logical discussion. The word "politics" is itself one of the most striking illustrations of this uncertainty of meaning. Some others which may be noted are democracy, American, Prussian, Puritan, etc.

It is true that in legal phraseology words are used with more precise and technical meanings. But the legal meanings are often different from the popular; and in some cases the student of politics finds need for terms in a more definite sense than that of popular use, but in some respects different from the technical legal meaning.

Perhaps this difficulty is to some extent responsible for the efforts of some sociologists to develop a distinctive technical terminology for their field, with the result, however, of increasing the complexity of the situation.

Political science and the other social sciences have not in recent times formulated laws of human action in such simple terms and mathematical formulas as the laws of astronomy, physics or chemistry, so as to enable accurate predictions to be made as to future actions or the results of particular acts of the government. Indeed, in this respect, the present-day student of politics and other social conditions is more cautious than those of former times. In the past, there have been formulated periodic cycles of political and social changes, and at the end of the eighteenth century such dogmas as the equality of man and of states, the social contract, the separation of powers and the balance of powers in international relations, were widely accepted by political writers, and formally established in constitutions as the legal basis of political institutions. Some of these legal formulas to-day hamper political development, but the scientific student has understood for a good while that they are not precise statements of universal truths. In somewhat the same way, present-day scientists in other fields are learning that some of the simple mathematical formulas previously accepted are but approximations, satisfactory for working purposes under certain condi-

[24] *Cf.* President Lowell's remark that the study of politics "lacks the first essential of a modern science—a nomenclature incomprehensible to educated men." Presidential Address, *American Political Science Review,* IV, 1.

tions; but that more complex and involved equations must be worked out to meet a wider range of conditions.

But if some of the older formulas are no longer accepted as accurate and complete, the study of politics and social life leads, as in the case of the physical sciences, to the framing and acceptance of general propositions which indicate the results of certain kinds of actions. These propositions in all the social studies are less definite than those of the physical sciences. They show tendencies which may be offset by other factors, some of which may be recognized, though not even roughly measured, while others may not be clearly identified.

Of the social studies, the generalizations of economics are the most definite; and such "laws" as those of supply and demand, diminishing returns, the Malthusian law of population and Gresham's law of competing currencies are stated with a good deal of precision, and in some cases can be expressed or applied in mathematical terms.

Legal science, the oldest of the social studies, has also general principles underlying the manifold specific rules of law. The principle of order has been said to be the most fundamental; and the reciprocal correlation of legal rights and duties is also among the most important.

In the field of politics generalizations rarely, if ever, in these days, take the form of definitely formulated "laws." But a considerable number of tendencies can be observed and described, and some of the results of certain political actions can be forecasted with reasonable accuracy.

If we trace political development from the time of the Greeks, we can see: (1) the abolition of human slavery and to that extent the establishment of the principle of human freedom; (2) the general adoption of the principle of representative popular government; (3) the clarification of the doctrine of legal sovereignty in the political system; (4) the more recent recognition of the distinction between the political state and society; and (5) the success of the federal principle as a basis of governmental organization.

Among the later adjustments, we may note that, if the social contract is no longer accepted as the basis of government, it is more clearly recognized that all governments derive not only their just powers, but all their powers from the consent of the governed;[25] and the present tendency is to replace tacit consent by a more posi-

[25] "Even where there is an absolute monarchy, this is so. The king may claim to rule as of divine right. . . . But even so, the acceptance of the command depends on the faith of man in the divinity of its origin. Such a faith is only a form of general opinion, however important it may be, and so back to its foundation in general opinion the basis of sovereignty is always brought." Haldane, "The Reign of Relativity," Ch. 7.

tively expressed assent. So, too, if the eighteenth century doctrine of the separation of powers is no longer considered as essential to political liberty, it is more widely accepted that no one can be safely trusted to be impartial in his own case, and the importance of an independent judiciary is more actively urged.

In place of the three dimensional scheme of governmental powers, recent writers on politics, like the modern mathematicians, discuss four or five (or more) dimensions or categories of governmental functions. Political and social communities exhibit forces of attraction and repulsion, which vary, not only with their size and distance from each other, but also, as in the case of chemical affinities, with the internal characteristics of the several components. The psychological factor of fatigue is seen to be applicable to political activities, so that popular control of government may be weakened by requiring the voter to do too much.

In some respects changes in the generalizations of political thinking have been clearly affected by developments in the physical and biological sciences. The nineteenth century doctrines of the separation of powers and *laissez faire* individualism were related to a view of political and social organization based on Newtonian physics, in which the individuals were considered as somewhat like planets in the solar system. The later and equally dogmatic doctrine of Socialism has been related to the organic theory of political and social institutions, based on biology, in which the individual is considered as a cell in the larger organism of the social group or the political state.

To-day students of political and social affairs find both of these analogies unsatisfactory. Individuals in political and social communities are more closely related than the planets in the solar system; but they are not so completely absorbed in the larger groups as are the cells in a biological organism. In one respect, the social group seems clearly differentiated from the compound entities in the physical and biological sciences, in that the human individual (unlike the atom or the cell) may be and often is at the same time a member of a number of such social groups.[26]

[26] In a stimulating brochure, recently published, entitled "Des Sciences Physiques aux Sciences Morales," in which he has undertaken to demonstrate the application of mathematical methods to the moral as to the physical sciences, M. Jacques Rueff suggests the view that individualistic political economy may be compared to euclidean mathematics, applicable to practical conditions, while socialism he considers as a non-euclidean political economy, logically consistent with its own postulates, but not so convenient for the practical world of to-day. The general purpose of M. Rueff may be commended, but his applications are open to question. His analysis assumes that individualism and socialism are based on independent and contradictory assumptions. But at

An important problem in the psychology of the political and social group is that as to the nature of the general will or public opinion of the group, and this problem is also met in the legal discussions as to the juristic personality of corporations. Is there a real will or personality of the group, which is something more than the aggregate of individual wills and personalities? Whatever the answer is, it at least seems clear that the group or corporate personality does not completely absorb that of the individual members; and that the personality of the group is not more highly developed, but is less complete than that of at least some of the individual members.

If we turn from such limited generalizations, which have some analogy to the laws of physical sciences to more comprehensive hypotheses, such as M. Du Sablon considers the most important achievements of science, it may be of interest to note an instance where a student of politics seems to have anticipated by nearly half a century ideas recently presented as novel by present-day physical scientists and philosophers.

Fifty years ago, Walter Bagehot, an acute observer and writer on politics and economics, in his well-known work on "Physics and Politics," in which he applied some of the methods of scientific reasoning to political phenomena, undertook an analysis of the conditions underlying political and social progress. He noted as the first of these conditions the need for fixed and stable customs, developing into law; but that this stage of fixed custom must be supplemented by elements of change resulting from the original inventiveness of man. "Success in life, then, depends . . . more than anything else on animated moderation; on a certain continuation of energy of mind and balance of mind, hard to attain and harder to keep."[27]

This combination of stability and variety may be compared with

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least some students of social problems hold that the individual and society are but two aspects (or shall we say dimensions?) of the same phenomena; and combine them in one correlated system. On another basis it may be suggested that both individualism and socialism may be classed as sub-euclidean systems, based on not more than two dimensions; since both assume human nature as moving only in the one plane of logical reasoning. A more comprehensive science would seem to call for a recognition of emotions as a basis of human action, to form a workable euclidean three dimensional system. Perhaps other factors might also be considered as a basis for super-euclidean systems of social science.

[27] Or as stated by a recent writer: "The double law of politics is that sitting still is commonly wrong and forcing the pace is commonly disastrous." *Times Literary Supplement,* Aug. 31, 1922.

the views of Lawrence J. Henderson, a biological chemist, in his "Order of Nature" (1918), where he discovers the underlying condition of progress or evolution in the world of matter in the great variety of relatively stable compounds made possible by the characteristics of the more common chemical elements—oxygen, hydrogen, carbon and nitrogen. So too, in the field of biology, the evolution of species is ascribed to variations and mutations from stable inherited factors.

It may also be compared with the thesis of Professor Dewey, in his "Human Nature and Conduct," in which he finds the underlying factors of human character to be those of fixed habit and original impulse, and that improvement is to come through the intelligent correlation of these factors of stability and change.

Custom and initiative, stability and variety, habit and impulse, law and liberty—are these not varying expressions of the same fundamental paradox of the universe?

We seem to-day to be living in a time of radical, if not revolutionary, change. The indivisible and stable atom has been disintegrated and resolved into impulsive electrons. The foundations of physics have been shaken; and even the adequacy of euclidean three dimensional space is challenged by the doctrine of relativity.

So too, in the world of public affairs, the old order of stable custom has been thrown into confusion by the explosive impulse of war and revolution; and the whirling chaos of political electrons is seeking, though but slowly attaining, a new stability, with a larger synthesis in the League of Nations. In our own country, where the congealing habits of political institutions were but slightly melted by the heat of the distant explosion, the demand for normalcy has shown a tendency to return to the former status detached from the new world order. But it may be hoped that in the reaction from the chaos of Europe our political system may not become so petrified that another catastrophic explosion will be required to permit further development.

Under these circumstances, it is not surprising that recent writers on political problems have been less sanguine as to a general tendency to progress in human affairs. Even before the World War, Henry Adams, accepting the second law of thermodynamics as more firmly established by physical science than the doctrine of progressive evolution, had found the same degradation of energy in the history of civilization since the thirteenth century.[28] In the last volume of his comprehensive "History of Political Theories," Professor William A. Dunning, while recognizing developments in

[28] "Letter to the teachers of history" (1910), published in "The Degradation of the Democratic Dogma" (1919).

political institutions, could find, in the solutions proposed for the fundamental political problem of the basis of authority, no advance in the essential ideas beyond those of Greek thought. Lord Bryce, in his monumental work on "Modern Democracies," also strikes a note of disappointment as to the results of the democratic movement of the nineteenth century, though retaining a gleam of hope for the future.

In conclusion, however, we may say that there is a science of politics which, like other sciences, begins with certain accepted postulates, and by means of observation, experiment, comparison, subjective analysis and reasoning, has reached from time to time certain relatively stable principles; but that under the impulse of new facts and new ideas these principles are subject to modification and at times to sweeping changes. Whether such variations are all in the direction of progress, it may at least be said that they are signs of life, and that without them politics, and other sciences, would have reached the perfect stability of death.

THE DOG AS A DETECTIVE

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I

Before the abolition of slavery in this country, dogs were much used in tracking runaway slaves; and as the dogs were so much used for this purpose, it was but natural that they came to be employed also in tracking and searching out criminals and other persons who were wanted by the police. And it became the practice in American courts, a practice which still exists in most of our states, to admit as evidence the statements of witnesses as to what a "bloodhound" has done in tracking an accused party. The employment of the so-called "bloodhounds"—many of which were really foxhounds or dogs of other breeds—declined after the abolition of slavery. But in the present century the utilization of dogs in the criminal service has received a new impetus from the movement to introduce police dogs into the United States, following the precedent of the systems of dog police in Belgium and Germany and other parts of Europe. The police dogs are truly useful in a great variety of services, and we hope to see them tried out and put into actual practice in this country, on a much larger scale than has yet been attempted. But the employment of dogs as detectives and the acceptance of their behavior as evidence that may lead to the conviction of a suspected person is so serious an undertaking that it should be permitted only on condition that we have full and accurate knowledge as to the capacities and limitations of the dog detective.

The fact is that the achievements of dogs in detective work have been greatly exaggerated. This conclusion has been reached as a result of experience with the canine police in actual practice and also of experimental tests held at Berlin under the auspices of the German government. The tests were conducted by a number of persons, especially Professor Pfungst, of whom we shall say more presently, and Police Lieutenant Konrad Most, who is one of the most scientific men engaged in the work of training police dogs. As a result of their findings the Prussian government has forbidden the use of police dogs in the criminal service.

A detailed account of the experiments is given in Most's book on the training of the dog for service with the police and the army and other organizations. Most's work is not yet sufficiently known

in America. For example, the *American Law Review* in 1920 printed an excellent article by J. C. McWhorter, entitled "The bloodhound as a witness," the purpose of which was to warn against the danger of convicting innocent persons, if we rely upon dogs to establish the identity of the persons in a case. Yet even the writer of this article apparently had not heard of Herr Most's work. If he had known of it, he would surely have quoted it, for it completely discredits the dog as a witness.

The fundamental claim put forth by those who advocate the use of the dog as a detective, the claim which was tested in the Berlin trials, is to the following effect: That the dog, if he be taken to the place where a crime was committed, or if he be presented with objects touched by the criminal, can, from the place or from the objects, "get" the scent of the individual who committed the crime; that he can remember this "given" scent or odor, and recognize it if he comes upon it at a future time; that he can pick up a trail having the given odor and can follow this trail infallibly, even if it is crossed by many other and fresher trails; that if the criminal mingles in a crowd, the dog can single him out by his odor and indicate him by baying at him or jumping on him.

The Berlin experiments, of which we shall now give a brief account, have demonstrated that, in regard to every item in this claim, the dog is thoroughly unreliable. The trials were open to all comers; nor was any entrant debarred from making a second attempt, in case the first attempt proved a failure. Among the entrants were prize-winning dogs from all Germany. The weather was favorable, and every precaution was taken to make the tests fair and accurate. The trials were concerned chiefly with four problems, which we shall mention in their order.

The first problem was to work out a fresh trail in proximity to other fresh trails. The tests on this problem confirmed the conclusions drawn by Herr Most from his long experience with police dogs, which he sums up thus: The dog can not be relied upon to follow the trail of one individual if other human trails cross this one, or even come near it. He switches easily from one trail to another, and often does this without hesitation, so that the trainer has no means of knowing that the switch has been made. If the alien trails are older than the desired trail, they generally do not lead the dog off; but if they are as fresh as the desired trail the dog is very liable to change to them. The angles made by the trails are important, because the dog has a tendency to continue running in one direction. An alien trail crossing at right angles is least likely to be taken up. If the desired trail bends at a sharp angle, and at or near the bend an alien trail happens to run in continuance

of the original direction, the dog almost always follows this alien trail. The same thing occurs if the desired trail traverses an unfavorable spot (for example, a much frequented street) and the dog, after crossing this unfavorable spot, happens upon a fresh alien trail.

The second problem was to work out a single trail when it was several hours old. The experimenters saw to it that the ground was absolutely free from alien trails. Twenty tests were made, upon eight different trails, the age of which was from five and a half to six and a quarter hours. The dogs failed in every test. The results indicate that a human trail ceases to be detectable when it is several hours old. A police dog can track a man most easily and surely if he is put upon the scent within a half hour from the time the man laid the trail.

The third problem was to single out an object, after being given the scent of its owner. Ten objects, belonging to as many persons, known as the test persons, were laid in a row on the greensward, each being laid down by its owner without being touched by any other human being. One of the dogs, named Flott, was brought in and allowed to "get the scent" from test person No. 3, this man holding both his hands around Flott's nose for 20 seconds. Flott was then told to fetch the object belonging to this individual. Obediently, he went to the row of objects and, after sniffing about for some time, brought No. 8, which was of course wrong, for he should have brought No. 3. In all, 17 trials of this problem were made. The number of objects used in a trial was never more than ten, and was often less. Nevertheless, in the 17 trials there were only two in which the dog fetched the right object. This is almost exactly the number of correct responses to be expected if the results were determined by pure chance. The outcome demonstrates that a dog, having been given the scent of a certain man by being allowed to smell his hands, is not able to single out from a number of objects the one that belongs to this man.

The fourth problem was the converse of the third; it was to single out a person, after getting his scent from an object belonging to him. Ten persons laid their gloves on the ground, then went to a distance and stood in a row, facing away from the spot where the gloves lay, and with an interval of three paces between each man and his neighbor. A dog was given the scent from one of the pairs of gloves, and commanded to single out their owner. In this case it was important that the test persons themselves should not know which pair of gloves had been smelled by the dog. Because, if one person had known that he was the "guilty" party, he inevitably would have expressed his thoughts in slight movements, different

from the movements of the other test persons, and this difference probably would have called the dog's attention to him. On the problem thus arranged, one dog was given four trials, without success. The number of trials in the present case was small, but the result confirms the conclusion derived from other evidence, which is that a dog, having been "given" the scent of a criminal from an object belonging to him, is not thereby enabled to single out this criminal from among other persons.

The trials which we have described were held in the year 1914. A similar series of trials was held a year earlier, with equally negative results.

Of the dogs tested in 1914, 11 were "German police" dogs (Schäferhunde), two were Airedales and two Dobermannpinscher. In the United States there is a popular notion that the bloodhound has a keener nose than any other breed. But this is a mistake, and if bloodhounds had been used in the Berlin trials the results would not have been essentially different.

In the beginning of this article we stated the fundamental claim that has long been made on behalf of the dog detective. We have now shown that the dog is unreliable in regard to every item in that statement. But that claim was extremely moderate as compared with the assertions made by some writers on the subject. A convenient summary of the affirmations formerly made by those who advocated the use of dogs as detectives can be found in the *Journal of Criminal Law* for 1912. This summary, which bears the earmarks of having been translated from some older German document, includes—in all seriousness—such assertions as the following:

> Small objects which have been left by criminals are best preserved in wide-necked bottles made of glass and sealed with glass tops; in case of necessity they may be kept in carefully washed preserve jars. As the human scent is preserved for weeks or months in such receptacles the dog can discover an accused person from among many others by taking the scent from the objects preserved in this way, even after a long lapse of time.

The meticulous care bestowed upon these bottles adds a touch of humor to the problem. The passage quoted, together with other passages in the same article, is an illustration of the fact that the belief in the dog detective developed not only into a tradition but almost into a superstition. This is an interesting chapter in human history, which will be further illustrated presently.

The conclusion to be drawn from all the facts which we have reviewed is that the dog should not be used as a witness. But a police dog is extremely useful in the performance of many other services. Herr Most says that in the work of tracking criminals a dog can be used in two ways: First, when a criminal is detected in the act, but escapes, a dog can be set on his trail at once, to follow

him by sight or sound or scent or all three combined; secondly, in cases in which the crime is not discovered until some time after the criminal has left the scene, the dog can still be used, but only as an auxiliary in the search. He may be able to work out a trail, or part of a trail, and thus assist the police in finding the evidence. The dog's behavior should not in itself be used as evidence.

The police dog is still trained to find lost articles. For in order to do this he does not need to distinguish the scent of one individual from that of another. If, for example, a purse full of money has been lost on a certain street, a policeman sends a dog back along that street, saying to him, "Verloren, verloren." In response to this word, the dog seeks and brings to the policeman any article whatever on which he detects the odor of a human being.

The dog is trained to find concealed persons in a house raided by the police. He is trained also to search a battlefield for wounded men, and to search a policeman's beat for persons who have fallen down in a faint or in a state of drunkenness or illness. In none of these tasks does he need to distinguish between individuals. In the training for the last two, he is simply taught to seek out any human being who is lying down.

We have shown that the dog is unreliable in tracking and identifying the individual criminal. Attention should be called to the fact that we have not discussed the dog's tracking power in general, and that this is a very much larger topic. Many more experiments are needed. One problem which needs investigation is this: It is doubtful whether any trainer has actually taught his dog to distinguish properly between two different commands, one of which, used in the search for wounded men, means that the dog is to seek any individual whatever, whereas the other command, used in the criminal service, means that the dog must adhere to the trail of a single individual. There are some experiments, notably those of Romanes upon his setter bitch, described in *Nature* in 1887, which indicate that a dog is comparatively reliable in following the trail of his (or her) own master. When seeking the master, the dog unquestionably does aim to adhere to his individual trail. Yet even Romanes found, in some of his tests, that his faithful setter bitch passed directly from his trail to that of a man who was a stranger to her, giving no sign that she was aware of the change. Modern experiments, with the refinements of present-day psychology, to test the ability of a dog to track his own master have not yet been tried. Nor have we any scientific data on the proficiency of the dog in tracking animals other than the human being. These are great fields of interest still waiting for investigation.

II

The puzzling fact remains that there are on record many actual cases in which the dogs that were used as detectives apparently did track the criminal and single him out from among other persons. How shall we explain these cases, which seem, on the surface at least, to contradict all that we have said? To begin with, we must admit the regrettable fact that on many occasions the acceptance of the dog's behavior as evidence has led to the conviction of innocent persons, especially in our own country, where dogs have been much used for tracking negroes. In the excitement of the chase, the white mob has not been particular as to the accuracy of their "bloodhounds" in tracking a single individual; they have accepted the result uncritically whenever their hounds "treed a nigger."

But there have been many cases, especially in Europe, in which the person tracked by the police dogs has confessed to the crime. And not only has it been proved that the dogs were right, but it has appeared that they possessed somehow a most astonishing, indeed an almost uncanny power of discovering the guilty person. The stories of these cases read like a romance—but the true explanation of them also reads like a romance. This explanation will become clearest if I preface it with an account of a certain horse who, like the dogs in question, exhibited powers which seemed at first almost unbelievable.

In the year 1904, and from then until the war broke out, all Germany was stirred to excitement over the accomplishments of certain horses, of whom the first and most famous was Clever Hans. This horse's owner, Herr von Osten, an old teacher of mathematics and a passionate lover of horses, conceiving the idea that a horse could be taught mathematics, had concentrated his efforts for years upon Hans, in an attempt to give him a mathematical education. His patience and perseverance were richly rewarded. Hans could at length answer almost any question in regard to figures and fractions, adding, subtracting, multiplying and dividing, even extracting square roots and cube roots. Such ability in a horse is contrary to all that is known regarding animal psychology. Hence, the case of Clever Hans was taken up with avidity by psychologists, especially by Professor Pfungst, the same who later superintended the experiments upon the police dogs.

Professor Pfungst found that Hans, when a problem in arithmetic was presented to him, gave the answer by pawing the correct number of times with his forefoot. And he gave correct answers to problems propounded to him by strangers, even when his owner was not present. This proved that Herr von Osten was honest; he had not trained his horse to answer by means of a code of secret

signals, such as is commonly used by professionals who train horses for money-making performances. Professor Pfungst then became convinced that every one who asked the horse a question revealed the answer by making slight involuntary movements, one sort of movement at the moment when the horse should begin pawing, and another sort of movement when it was time for him to cease; and that the horse was keen enough to observe these movements of the person in front of him and to regulate his pawing accordingly. This explanation proved to be the correct one. Hans knew nothing of mathematics, but he perceived with remarkable accuracy when it was time for him to stop pawing in order to win a prize of carrots or apples. Yet the involuntary movements made by Herr von Osten and the other questioners were so slight that Professor Pfungst was for a long time unable to detect them, no matter how closely he watched each questioner during a performance. And it was only after prolonged and elaborate research by psychological methods that he was able to give any adequate account of these involuntary expressions, to which he gave the name "minimal movements." These minimal movements play an important rôle in human psychology in the phenomena of suggestion and hypnotism, in the answering of questions by the ouija board, and in so-called telepathy, thought-transference or mind-reading, which is really muscle-reading. Professor Pfungst says: "Every horse that is good for anything is a muscle-reader; he reads the mind of his driver through the pressure on the bit—though not a word of command is uttered."

Hans was able not only by pawing to answer numerical questions, but also by other reactions to answer questions of various sorts. The following performance of his is so similar to the work of a dog detective that it can throw a great deal of light upon the latter. When confronted with a row of objects, Hans could select any one that was asked for, seizing it with his teeth and bringing it to the questioner. For example, when five cloths of different colors were laid on the ground, and Hans was told to fetch the red one, he executed this order correctly. Experiment showed that he had no knowledge whatever of the names of colors. His method of solving the problem was as follows: He walked along the row of cloths, beginning at one end, and making at least a slight movement of his head toward each cloth as he came to it. If the first cloth was not the correct one, he perceived in the movements of his master an expression of disapproval, or he heard an impatient tone in his master's voice. His tendency to reach toward the first cloth was thereby inhibited, so he passed on to the second. Thus he continued until he came to the correct cloth,

whereupon, his action being no longer inhibited by signs of disapproval, he seized this cloth with his teeth and brought it to his master.

Similarly, when a police dog is told to single out from a row of objects the one that has a certain odor, in some cases at least he is not guided by odor at all, but is governed by the expressions of approval and of disapproval on the part of his master; and by this *rapport* with his master he is caused to pass by all the objects in the row except one, and to fetch that one. There are some minor differences between the horse and the dog. For example, the horse, having his eyes on the sides of his head, can keep his master in view almost all the time, even when walking away from him. The dog is at a disadvantage in this respect. Other possible differences are not fully known, for the experiments upon muscle-reading in the dog were not carried out with the great elaboration of detail which characterized the experiments upon the horse. But the fundamental fact of dependence upon muscle-reading, which Professor Pfungst found true of the horse, he and Herr Most have found true also of the dog.

There are two sources of suggestion which have enabled the police dog in many cases to track a criminal to his hiding-place, and to single him out from among other persons: the first is the dog's master, the police officer; the second is the criminal himself.

The dog is always *en rapport* with his master and sensitive to the least hint or sign from him. This is especially true of the police dog, who has undergone a prolonged and severe course of training designed to render him absolutely submissive and obedient. In the practical work of tracking criminals, a policeman goes with the dog and generally holds him in leash. The policeman of course has a store of knowledge of criminals and their haunts, and very often when he starts out with the dog on a given case he has already made a shrewd guess as to the identity and the hiding-place of the person who committed the crime. When he has thus in his mind a certain theory on the case, it is impossible for him to inhibit the involuntary expression of his mind in his muscles. He can not help guiding the dog, no matter how honestly desirous he may be of letting the dog work out the trail unaided. Consequently, if the policeman strongly believes, for example, that the criminal is hiding in a certain house, the dog whom he is holding in leash will be almost sure to go into that house, because he will receive guidance in that direction from "minimal" jerks on the leash, or from the tones of his master's voice, or from a change in his master's steps or his attitude of body, the gestures made by his hands, or a change in the expression of his face, or from all these combined. If, on

the contrary, the dog's master remains in complete ignorance of the presumptive identity of the criminal and the location of his dwelling and all such details, then, as Herr Most says, the dog is unable to perform any of those miraculous pieces of detective work for which he has become famous. In experimental tests, from which we wish to determine exactly what the dog is able to do, every precaution should be taken to prevent him from getting the answer to his problem from the human beings present; indeed, the most conclusive tests of the dog's powers are made when no human beings are present at all.

We have said that the other source of suggestions that aid the dog in singling out the guilty person is the guilty person himself. This fact seems to have been especially prominent in the history of the so-called bloodhounds in our own country. When hounds were first used to track runaway slaves, the planters promulgated false stories as to the infallibility of these dogs in following a trail and their savageness in attacking the man whom they had pursued. These stories were believed by every one, and they were accepted as gospel truth by the poor fugitives, whose credulity was engendered in ignorance and intensified by fear. A fugitive who had disguised himself so cleverly that he could mingle in a crowd of men with a comfortable feeling that no human detective could recognize him, nevertheless trembled with awe upon the approach of a bloodhound, because he regarded this beast with an almost superstitious dread, and was firmly convinced that, do what he might to escape, the hound would come to him sooner or later, pounce upon him and reveal his identity to his human pursuers; and then, if the men did not quickly apprehend him, the dog itself would tear him to pieces. The fugitive's own fear thus betrayed him and led to his recapture. For the dog has apparently a natural tendency to perceive the signs of fear and to be excited by them; consequently, he barks at a person who shows fear.

But as time went on, negroes and criminals and escaped convicts gradually learned that bloodhounds are by no means infallible. Ceasing to show fear, they thereby ceased to betray their identity to the dog detective. And even if in some cases they were apparently singled out by the hound, this was no longer sufficient, as it had formerly been, to induce them to make a confession. The history of police dogs in Europe has been, in these respects, a repetition of the history of the bloodhound in the United States. Dogs were first used as part of a modern police force in 1899 in the city of Ghent, Belgium. The dogs immediately did splendid work in subduing the rough element of the city. Their praises were sung in the newspapers and magazines of the whole world. Their use

spread quickly to other countries in Europe and to Asia and America. They were a new weapon of attack upon the criminal, for which he was not prepared, and they had him thoroughly scared. The tracking of a criminal by a dog was in a great many cases followed by his confession. But now, after twenty years' experience, the criminals have learned that the dog is liable to error; consequently, the dog's witnessing against them does not force them to confess.

Thus it would appear that the extraordinary feats performed by dog detectives are matters of past history—partly true and partly legendary. The psychologists at Berlin have shown the absurdity of the exaggerated accounts of the dog's power of scent. In exposing this error, however, they have opened to us a new and fascinating field of canine psychology: they have given us a glimpse into the dog's powers as a mind-reader. But in this field, again, one must beware of the danger of exaggeration. The dog does not understand his master's purposes. He does not ask why in one case he is to seek only persons who are lying down, whereas in another case he is permitted to pursue a man who is running at full speed. He does not know that one man is wounded or sick, and that another is a criminal. The aim of the obedient dog is simply to behave in such a way as to win the approval and avoid the disapproval of his master. But he does this so keenly that he mirrors the thoughts of his master as faithfully as the hypnotized subject mirrors the thoughts of the hypnotist.

PLANT LIFE OF BRITISH INDIA

By Professor L. A. KENOYER

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No region on earth of equal size presents the climatic extremes to be found in British India. Here are all gradations of rainfall, from over 460 inches per year at Cherrapunji, Assam, to less than 3 inches in parts of Sind. Here are all temperatures, from a maximum of 128° F at Jacobabad to a minimum far below zero at the tops of the highest Himalayas. Hence, as we should naturally expect, the diversity of the vegetation and the number of species is very great. In Hooker's "Flora of British India" are described 17,000 species of flowering plants, while in Gray's "Manual of the Central and Northeastern United States and Canada" are less than 4,000. Yet the area covered by Hooker is hardly twice that covered by Gray.

Perhaps the most striking thing about the flora of India is its lack of peculiarity. An astonishingly small proportion of the genera and none of the families are endemic, that is, restricted to India. The great bulk of the species or their immediate ancestors have come in from adjacent lands or from neighboring lands overseas. Sir Joseph Dalton Hooker, than whom there has been no greater authority on Indian botany, says that in a large sense there is no Indian flora proper. The Malayan element is the dominant one, but intermingled with it are large numbers of plants from the Western Asiatic, European, Arabo-African, Siberian and Chinese floras besides a small but increasing number of American plants. The Chinese and Malayan forms abound in the east, the European, Western Asiatic and African in the west, while the European and Siberian are most plentiful in the Himalayas.

In India are represented all the leading types of the world's vegetation with the exception of the prairie. High temperatures, such as prevail over much of the area, are said to be unsuited to herbaceous grasses. Furthermore, a markedly periodic rainfall seems to be better adapted for trees, because they can draw upon the subsoil reserves of water during the dry season. There are usually grasses in abundance mixed in with the forest trees or with the desert scrub, but there are no large areas of pure grassland. Practically the entire peninsula is so completely under the sway of the monsoon conditions—the periodic recurrence of rainy and dry seasons—that it supports a vegetation decidedly periodic in its be-

FALLS OF THE NIRBUDDA RIVER, CENTRAL INDIA, WITH MONSOON FOREST IN THE BACKGROUND

havior. In most of India this is the monsoon forest of the plant geographer. In the west it grades into the thorn forest, the scrub and the desert, with gradually decreasing amounts of rainfall. In the portions with greatest rainfall, as the southwestern coast with its bordering mountains and the general region of the Ganges delta, there are so many evergreens that the plant formation approaches the tropical rain forest in character. It is doubtful whether even here we can consider it a typical rain forest, for it is subject to a rainfall of decidedly periodic distribution.

In the northeastern United States the leading five families of plants are Compositae, Cyperaceae, Gramineae, Rosaceae and Leguminosae, while in India they are Orchidaceae, Leguminosae, Gramineae, Rubiaceae and Euphorbiaceae. The Compositae is seventh and the Cyperaceae eighth in numerical importance in India. The orchids, which take the lead in India, are most numerous in the humid eastern Himalayan region.

The writer is most familiar with that portion of India which is known as the Upper Gangetic Plain, a comparatively level tract extending about 600 miles northwestward from Benares and occupying a breadth of about 200 miles between the abrupt rise of the Himalayas on one side and that of the Vindhiyan plateau on the other. This is a vast expanse of river alluvium, thousands of feet

in thickness—the débris of the Himalayas and of the much older plateau of peninsular India. It is almost level except where the rivers and their tributaries have cut deep gullies into the easily eroded silt. Supporting an agricultural population of 400 to 700 per square mile, it is practically all in cultivation except where the soil is too alkaline or too much eroded. The cutting of timber and the intense grazing of waste areas together with cultivation have reduced the forest which formerly occupied the area to a few straggling trees of types capable of undergoing the most strenuous treatment. Prominent among these are certain Leguminosae, such as *Dalbergia sissoo, Butea frondosa, Acacia arabica* and *Albizzia lebbek.* Butea, which is sometimes called the "flame of the forest," forms extensive groves on level tracts of land. In March the leafless tree is an impressive sight with its mass of shiny orange-red flowers. The pod hangs with a seed at the distal end, the remainder being flattened into a wing six to eight inches long for the dispersal of the seeds. The large leaflets are sewed together to make baskets and plates for household use. Acacia is the source of gum arabic and many other useful products. It is a native of northwest India, Arabia and Egypt, but has escaped everywhere on the Indian plains. The "Neem tree" (*Melia azadirachta*) is a graceful tree which springs up spontaneously almost everywhere.

One can scarcely conceive the extent to which vegetation has been modified. India has a very dense human population, 320,-000,000, and supports nearly half as many cattle, or, if we count domestic animals of all sorts, nearly as many as the human population. In a large portion of the Gangetic plain each acre must sup-

Zizyphus oenoplia, A THORNY PIONEER SHRUB OF GRAZED AREAS

port one person and one domestic animal. As cattle are considered sacred animals, those of no economic worth are allowed to run at large, grazing where they may. This intensive pasturage has a profound effect upon vegetation. Wherever animals graze, the plants that persist belong to three categories—those that are protected from animals by spines, those that are not eaten because of a bitter or unpalatable flavor and those that have buds next the ground where they can not easily be reached by animals. The spines of the great majority of spiny shrubs and trees, as species of Acacia, Capparis and Zizyphus, are modified stipules. In Zizyphus one spine points forward and the other curves backward, so the animal is caught in both the advance and the retreat. To the class with protected buds belong the grasses, of which there are many species, and a number of tufted mat-forming deep-rooted perennial herbs. Government experiments on afforestation show that when animals are kept off a tract of land a good growth of trees takes place in a few years.

A given area is subject to far greater extremes of humidity than is often experienced in temperate zone habitats. 90 per cent. of the rain falls in three months, from the middle of June to the middle of September. During the rainy period a given area may be wet meadow, or, if the soil becomes waterlogged and drainage is inadequate, it may, towards the close of the period, become a swamp or a lake. After the rains cease it gradually dries, and for six months or more is capable of supporting only a xerophytic flora. A lake in temperate America has around its margin vegetation zones made up of plants suited to different depths of water or to different amounts of soil moisture. The water level in most cases changes somewhat during the season but not enough to cause any serious disturbance in the established zones. In India the change of level is so rapid and thoroughgoing that we find, as a rule, no permanent zonation. There may be a temporary zonation—a border of small annuals growing near the water's edge and receding with the drying of the pond. A plant frequently present in such situations is *Glossostigma spathulatum*, a minute member of the Scrophulariaceae, which probably grows from seed to maturity in three or four weeks, hence is able to complete its life cycle before the substratum becomes too dry.

Common on the plains and over large portions of India are flourishing groves of planted trees. Perhaps the most important of these is the mango (*Mangifera indica*), a fruit native to and highly prized throughout India.

In the peninsula to the south of the Gangetic plain there is much hilly and rocky land. The population is less dense, hence

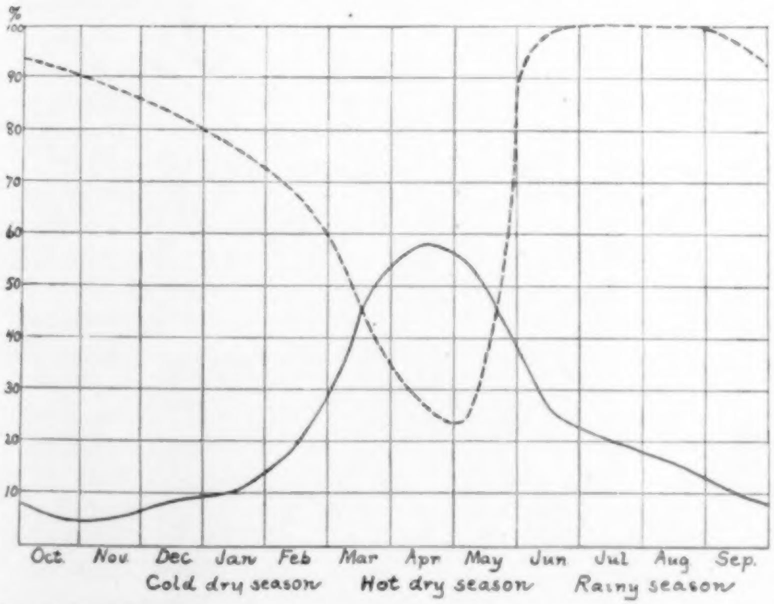
Sterculia urens IN LEAFLESS CONDITION, WHICH PERSISTS FOR MONTHS. FRUIT RIPE. [CHITRAKOT, DECEMBER 1920.]

trees have a fairly good opportunity to become established. The eternal quest for fuel prevents them from becoming very old, but in some localities are government reserves where the trees are protected from cutting long enough so we may form a conception of the aspect of the monsoon forest. In one of these forests in April, when the thermometer reaches a daily maximum of about 110° F, the trees are so bare that it is with difficulty that one finds shade from the broiling sun. Such few evergreen trees and shrubs as exist are found in the ravines where the water supply continues for a longer period.

The trees of the tropical monsoon forest are not so uniform in their behavior as are those of the temperate winter-deciduous forest. In the latter, the coming of frost seems to determine to a large extent the time of the shedding of leaves, while in the former there is no definite time for the leaves to fall. Some species, as *Erythrina suberosa, Bombax malabaricum* and *Sterculia urens* shed their leaves about a month after the close of the monsoon rains and remain naked for seven or eight months. Others, such as *Bassia latifolia* and *Melia azadirachta,* keep their old leaves until almost time for the new ones to appear, hence are leafless for less than a month. In fact, some of the trees are not at any time entirely leafless. For a number of years I have watched the leaf-fall of a tree of *Artocarpus lakoocha.* The shedding begins at the tip of the tree and passes in a wave towards its base, the whole process occupying

about a week. Before the leaves fall from the lowermost limbs the new crop on the topmost limbs is well advanced. The time for the changing of foliage in trees of this type may be, in different species, anywhere from January to April. The rainy season commences late in June or early in July, but few, if any, of the trees await its coming for the development of their new leaves. On the contrary, many of them will go through a long period of severely dry weather clothed in the tender new foliage. The stimulus that impels leafing is not very well understood, but the increasing temperature of spring would seem to have some bearing on it. There appears, also, to be a relation between reproductive activities and the appearance and disappearance of foliage. A young tree, or one which for some other reason does not blossom, retains its leaves after a blossoming tree of the same species has dropped its foliage. *Odina wodier* is a diecious tree of the Anacardiaceae. Shortly after the flowers drop the male tree begins to put forth its leaves, while the female tree does not open its leaf buds until the crop of fruits is mature.

A single species, even, in the monsoon forest is quite erratic in its behavior. We expect in the temperate forest to find the white oaks or the shellbark hickories doing practically the same thing at one time. But, for example, if we go in late April into a persimmon (*Diospyros tomentosa*) grove in central India we should find trees



RELATION BETWEEN LEAFINESS AND FLOWERING IN INDIAN MONSOON FOREST
The broken line represents percentage of leafiness, the solid line percentage of trees in flower.

with last season's foliage complete, shedding trees, bare trees and trees putting forth new leaves. We should find flower buds, flowers and fruits in different stages of development. One has difficulty convincing himself that the trees all belong to the same species.

There is a reciprocal relation between leafing and flowering in the monsoon forest. In the figure the broken line shows the average percentage of leafiness of 100 representative species of trees of the monsoon forest as determined by the writer in several different localities at different times of the year. The solid line shows the percentage of the same 100 species found in blossom month by month, the time of blossoming given in Brandis' "Indian Trees" being used. It will be seen that the highest point of the blossoming curve almost coincides with the lowest point of the leafiness curve, and vice versa. The development of the blossom buds may draw moisture from and hasten the fall of the leaves. In the distribution of pollen and the later distribution of fruits, there is no doubt an advantage in having the tree free from leaves.

The monsoon deciduous trees have for the most part scaly buds, but the scales are less conspicuous than in most of our winter deciduous trees. In the forests of the plains there is a scarcity of herbs with fleshy perennating organs, as bulbs and tubers.

Perhaps only one tree of the central Indian forest escapes com-

THE "MAHUA" (*Bassia latifolia*), A MONSOON DECIDUOUS TREE OF THE PLAINS, SHOWING HOW THE LEAVES ARE SHED FROM THE TOP DOWNWARD

Odina wodier, A MONSOON DECIDUOUS TREE, WITH FRUITS. HOT DRY SEASON

pletely the woodsman's axe. This is the "mahua" (*Bassia latifolia*). Its spherical fleshy white flowers, rich in sugar, fall to the ground in the early morning and are gathered to be eaten fresh or dried or to be made into "sharab," one of the favorite distilled liquors of India. Its fruit is edible, and its seed yields an oil valuable in cooking and for medicine.

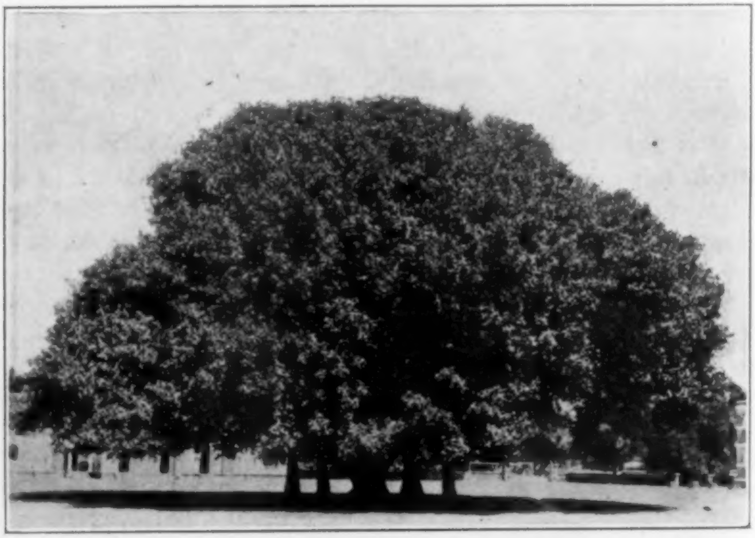
The teak (*Tectona grandis*) is an exceedingly valuable forest tree in Burma and only somewhat less so in central India. Its wood is highly prized for cabinet work. It is a typical monsoon tree, its large simple elliptic leaves, which sometimes attain a length of two feet, lasting only a little over half a year. It is of such widespread occurrence that it might be considered the dominant tree of the climax monsoon forest.

The genus Ficus is a noteworthy one among Indian trees. Its best-known representative is the banyan (*F. benghalensis*), a single tree of which, by reason of its widespread branches and the prop roots which sustain them, may resemble a small grove. A tree in the Calcutta Botanical Gardens has about 500 of these prop-roots and covers two acres of ground. *F. religiosa*, the "pipal" or "bo" tree, was regarded sacred by the Buddhists, who occupied India twenty centuries ago, and is still so considered by the Hindus. Many a devotee places before the tree a small lighted lamp or an offering of food or flowers to appease the spirit which is supposed

to inhabit the tree. The leaf has a long attenuated tip designated by Kerner as a drip-tip and said to be advantageous in draining surplus water from the leaf. But any such advantage is doubtful, since the leaf hangs downward in such a manner that water could not in any case remain upon it, and since the tree is native to a portion of India where the rainfall is not excessive. Of considerable interest, also, are the strangling figs, as *Ficus rumphii,* which begin growing in the crotch of another tree, then surround the sustaining tree with a network of roots extending downward till they strike the soil. On the death of the sustaining tree this skeleton root system may be strong enough to support the Ficus.

Bamboos, particularly *Dendrocalamus strictus,* are abundant in many parts of the forest. This is not a particularly large form, but it forms conspicuous clumps in places. In famine years its leaves are of some value as a cattle fodder, and the grain, which is spasmodically produced, is a good substitute for wheat.

Mention should be made of the palms, two of which, the wild date (*Phoenix sylvestris*) and the palmyra (*Borassus flabellifer*), are common, wild or planted, over a great portion of India. The latter is used as a source of fans and for the making of a popular alcoholic liquor. Both have been utilized in the manufacture of sugar. The cocoaunt palm is restricted to the regions near the coast, especially southward. Kipling's words, "we hold dominion over palm and pine," may be exemplified within a very small com-



THE BANYAN (*Ficus benghalensis*), SHOWING FOUR LARGE PROP-ROOTS WHICH HELP TO SUSTAIN THE BRANCHES

A STRANGLING FIG (*Ficus rumphii*) WHICH HAS GERMINATED IN THE CROTCH OF A LIMB AND SENT ITS ROOTS DOWN TO THE GROUND

pass in certain parts of the outer Himalayas, for the uppermost palms (Phoenix) just reach the lowermost pines (*Pinus longifolia*).

The forest type just described covers the greater part of peninsular India and is doubtless the largest monsoon forest in the world. About Madras, where most of the rain comes with the northeast monsoon during the winter months, the aspect of the vegetation seems to change. Here is probably a greater percentage of evergreens with broad thickish leaves, such as we often find in areas with the rainfall limited, but distributed through the year. Here along the sandy shore are groves of beefwood (*Casuarina equisetaefolia*), a tree which at first glance suggests a pine, but which on

close examination is seen to have fluted and jointed branchlets, with scale-like leaves, much resembling those of Equisetum. It is used mainly for fuel. In Bengal and Assam, in Burma and along the Travancore coast, the increased rainfall increases the number of evergreens of the rain forest type. The dense impenetrable jungles of the type familiarized by Kipling are found mainly in the hilly regions of the southern tip of the peninsula, although a jungle is in reality any uncultivated piece of ground, whether growing in trees, shrubs or grasses.

The present Indian flora contains many introduced plants, American ones being especially prominent. It is said that about the year 1800 an effort was made to introduce the cochineal insect from Mexico into India. A species of prickly pear (*Opuntia elatior*) was taken over to serve as its food plant. The insects did not thrive, but the cactus is now to be found growing all over the drier parts of India, planted in fencerows or growing spontaneously. In the famine year of 1918–19 thousands of cattle in the Bombay Presidency were saved by its use, the cactus being first singed with a gasoline torch to destroy the prickles, then chopped and mixed with concentrated feedstuffs. Species of agave from tropical America have also been widely planted. American forms are numerous among the ruderals and weeds. Among other widespread ones are the Mexican poppy (*Argemone mexicana*), the spiny amaranth (*Amaranthus spinosus*) and *Tridax procumbens*, one of the Compositae which distributes its seeds, as does the dande-

JUNGLE OF *Ficus glomerata*, TERMINALIA ARJUNA, AND THE LIANA *Phyllanthus reticulatus*, IN A VALLEY ON THE VINDHIYAN PLATEAU

lion, by a windborne pappus. *Galinsoga parviflora,* a weak-looking South American Composita which has recently found its way into many of our cities in the United States, has become widely distributed over the Himalayas in India. The upper Gangetic plain alone has no fewer than twelve American Compositae, some of them so recent that they have not been included in the manuals. There is no more fascinating story in the realm of botany than that of the occupation of new territory by plant immigrants.

The really thrilling field of operation for the botanist in India is the Himalayas. Here, in a zone of 50 to 75 miles breadth, we have condensed, as it were, the plant formations of the world from the equator to the poles. Starting from Kathgodam or from Dehra, we may pass through tropical and subtropical monsoon forest zones, a warm temperate semiarid pine forest of trees allied to our southern long-leaved pine, three distinct oak forest zones, a cold temperate deciduous forest of maples, elms, alders, buckeyes, poplars and the like, a forest of cedar, pine, spruce and cypress allied to our northeastern evergreen forest, a subalpine forest of fir and white birch, an alpine shrub zone, alpine meadows and, at last, perpetual snow.

The hills rise quite abruptly from the plain. At their foot the seepage, together with the heavy rainfall that comes from the condensation of the moisture in the landward-moving air currents at this place, give rise to a dense jungle. Here the elephant and the tiger abound, where civilization has not encroached too closely upon their haunts. Here in the tertiary geologic period were the ancestors of the present-day elephant, the fossil remains of several species having been discovered. There are really two vegetation zones at the foot of the hills. A few miles out are swampy areas occupied by grasses, rushes, cat-tails and a few scattering trees, among which *Bombax malabaricum* is conspicuous. Nearer the base of the mountains, where the débris is coarser and the drainage better, a dense forest is supported. In this zone and on the lower slopes of the hills is found the "sal" (*Shorea robusta*), one of the most useful timber trees of India. It forms almost pure stands of tall remarkably straight trees conspicuous by their black bark and dark green foliage. In the zone just above this the leading trees are several species of Bauhinia. These are leguminous trees easily recognized by the twin-leaf, two leaves having apparently grown together to form one. A number of other tree Leguminosae are here represented. In April, when the foliage is scanty, several of the trees are in bloom, making the forest gorgeous with masses of scarlet, purple, white and yellow. Woody climbers and mistletoes are abundant in this zone.

The long-leaved pine (*Pinus longifolia*) forms almost pure for-

OAK WITH HANGING "MOSS"
Quercus semecarpifolia, with the lichen Usnea on its branches. [Nag Tiba, 9,500 ft. June 1917.]

ests along the crests of ridges and in other dry exposed situations. Its foliage is very sparse during the dry season. It is useful as a source of resin and lumber.

The broadest zone of all is occupied by the silver-leaved oak (*Quercus incana*). It is conspicuous at a distance by the silvery sheen of its lower leaf surface. Above this is the holly-leaved oak (*Q. dilitata*), with its leaves smooth and shiny green on both sides, while in a still higher zone is *Q. semecarpifolia,* which has a copper-colored pubescence on the lower surface of the leaf. These oaks

are evergreen with the exception of the last, which may be bare for a short period. Growing in an altitude in which winters are not very severe nor summers very dry they have adopted a leaf habit which enables them to take advantage of any favorable periods for foodmaking throughout the year. The Himalayan oaks all belong to the biennial-fruited division, and like most representatives of this division they are of little value for lumber. Yet no tree is more sought after by the hill resident. Near the village the trees are grubbed out so that the land may be tilled; just beyond this they have been cut for building timbers, for fuel or for making charcoal; still farther out the branches have been mercilessly lopped off for use in thatching, as cattle fodder during the cold and the dry seasons, as fertilizer for the fields or perhaps for the tanning of leather. It is due to its wonderful power of recovery that the oak remains so abundant.

In the ravines of the oak forest are several evergreen members of the Laurel family, the box, the holly and a beautiful flowering dogwood (*Cornus capitata*) similar to our *Cornus florida*. Mixed with the oak are two trees of the Heath family, *Rhododendron arboreum*, which is resplendent in the spring with red bell-shaped flowers three inches long, and *Pieris ovalifolia*, with waxy-white drooping urn-shaped flowers. While the greater proportion of the trees of this zone belong, as does the oak, to the broad-leaved sclerophyll group, there is quite a sprinkling of winter-deciduous forms, among which are a Prunus, a Pyrus and a Crataegus. At least four species of barberry are found here, and on some of them may be seen the aecial stage of the wheat rust.

Our consideration of the hill vegetation should include some remarks concerning especially modified forms. Lianas are abundant, particularly in the lower zones. The largest is *Bauhinia vahlii*, known as the elephant creeper. As much as one fourth of an acre of forest has been covered by a single plant of this huge climber. With its large elephant-ear leaves and its velvety bean pods 18 inches long, it gives a semblance of reality to the story of Jack's beanstalk. There are a number of climbing aroids, besides species of Ficus, Vitis and other plants with a similar habit. The hemiparasitic mistletoes abound. Loranthus and Viscum are the leading genera, but on *Pinus excelsa* may be found the tiny *Arceuthobium minutissimum*, said to be the smallest dicotyledon on earth. There are several hemiepiphytes, like the strangling figs, which start as epiphytes and later make connections with the ground. There is a host of true epiphytes, including lichens, mosses, ferns and flowering plants. At the height of the rainy season the branches of the oak, in particular, are almost masked with the profusion of

Hygrophytic Vegetation near a Waterfall at 5,000 Feet in the Himalayas

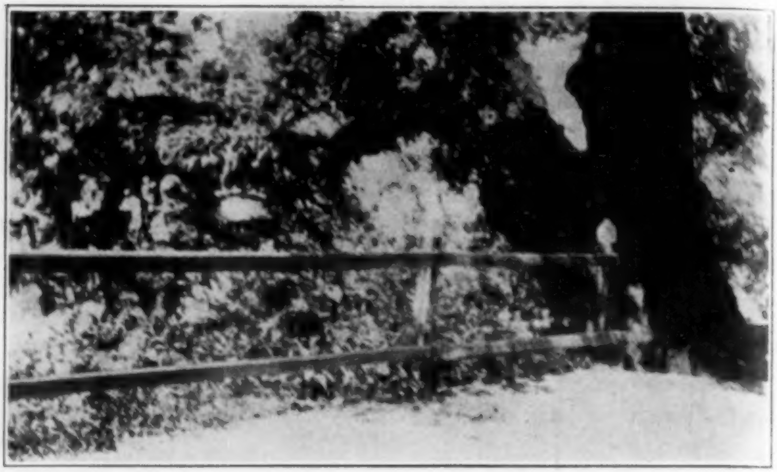
these epiphytes. In the higher oak forests is an abundance of the lichen Usnea hanging in long streamers from the branches of trees.

The undergrowth of the hill forests resembles in large degree that which we find in our temperate forests, with the addition of certain tropical families, as the Begoniaceae, Gesneriaceae and Zingiberaceae. In the spring are found representatives of the temperate zone families, such as Ranunculaceae, Cruciferae, Caryophyllaceae, Violaceae and Crassulaceae, while after the beginning of the rainy season in June the representatives of the tropical families are at their best. Then come goldenrods, asters and Senecios, similar to those found in the temperate forest in autumn.

Beyond the range of the oaks we encounter a sprinkling of alders, elms, maples and other winter deciduous trees, mainly in the valleys. Above this the higher coniferous forest is encountered. Its dominant tree in the western half of the range is the deodar or Himalayan cedar, a near relative to the Cedar of Lebanon. "Deodar" signifies "gateway to God," and the tree was well selected to symbolize divinity, for no tree surpasses it in beauty and symmetry. Like *Ficus religiosa* on the plains of India, *Cedrus deodara* in the hills is everywhere associated with temples and shrines. Mingled in the deodar forest, but principally around its edges, are found the blue pine (*Pinus excelsa*), the spruce (*Picea morinda*) and the Himalayan cypress (*Cupressus torulosa*).

The uppermost Himalayan forest is a mixture of *Betula alba* and *Abies webbiana*. This species of birch extends around the world in the subarctic regions, and with it may be associated species of fir. On the Himalayan mountain sides the dark fir trees stand out conspicuously against the white birch. At 10,000 feet the writer found the birch trees just coming into leaf the middle of

HIMALAYAN CEDARS (*Cedrus deodara*) GROWING BESIDE A PATH



BRANCH OF *Quercus incana* LADEN WITH FERNS AND OTHER EPIPHYTES. HIMALAYAS AT 7,500 FEET

June. At greater elevations the firs drop out, leaving a birch forest with a slight admixture of mountain ash and shrubby rhododendron. So great is the accumulation of snow in winter that at times the birch trees lie prostrate on the ground.

Above the forest is a shrub zone made up largely of spreading junipers (*Juniperus communis* and *J. macropoda*) and the peculiar Equisetum-like *Ephedra vulgaris*, with bush rhododendrons and other forms. An element of the depauperate Tibetan flora comes in places through the high mountain passes and occupies the Indian side of the range. Above the shrub zone is the mountain meadow with its buttercups, primroses and cinquefoils, the vegetation becoming more and more scanty as greater heights are reached. More than 30 species of flowering plants have been found at the altitude of 18,000 feet. This is ordinarily considered as about their upper limit, but the Mount Everest expedition of 1922 found the edelweiss flowering at almost 20,000 feet. Even above this tremendous height it is more than 9,000 feet or almost two vertical miles to the "top of the world," a monotony of bare rocks and snow unbroken by vegetation except, probably, a few lichens.

The flora of Nepal, a kingdom occupying about 500 miles of the length of the Himalayas in their central portion, is practically unknown, but we have some evidence that this is a sort of transition zone between the Eastern and Western Himalayan flora. The Eastern Himalayas, on account of their warmer, moister climate have a flora which is more luxuriant and more largely tropical than that just described for the Western Himalayas.

A South-facing Slope at 4,500 Feet Altitude, Western Himalayas. In the Valleys Mostly *Quercus incana,* on the Ridges Grassland, at the Crest Pinus longifolia

The following will show the parallelism between the vegetation zones encountered in travelling northward in eastern North America from the southern tip of Florida to northern Labrador, and that found in a journey from the base to the summit of the Himalayas. In the former case the crossing of these zones would involve a journey of about 3,000 miles, while in the latter 60 miles in direct line would suffice.

America	*Himalayas*
Tropical forest	Shorea-Bauhinia forest
Southern mesophytic pine forest	Pinus longifolia forest
Live oak, water oak, laurel oak, etc.	Oak zones
Beech-maple forest	Maples, alders, elms, etc.
Northern coniferous forest	Upper coniferous forest
Birch forest	Birch forest
Tundra	Alpine shrub and mountain meadow

Thus India, about half the size of the United States, is a vegetational world in itself and embraces a horde of botanical problems, the solution of which, aside from contributing to the maintenance of the vast underfed population, will cast much light on the larger problems of the world's plant distribution and plant behavior.

THE CULT AND EARLY ECONOMIC ORGANIZATION

By Professor HERBERT MAYNARD DIAMOND
NEW YORK UNIVERSITY

THE PRIMITIVE STRUGGLE FOR EXISTENCE

As a general thing we do not to-day club our aged relatives on the head with the kindly intent of settling for them once for all the problem of living. Indeed, contemporary society views such conduct with some little disfavor. However, on this continent some groups of our aboriginal predecessors not only pursued this practice but regarded it as quite the sporting thing. Life necessities compelled resort to some such expedient. The old, who could no longer engage in the chase and no longer endure the constant physical exertion demanded by a wandering life, were far too great a burden for the active to carry. Hence, as in several other parts of the globe, this primitive solution of the matter.

It would be difficult to select an illustration indicating more forcibly the differences in the character of the struggle for existence as between civilized and uncivilized men. The life problems of each differ profoundly. Men of advanced culture have thrown up barriers between themselves and the operation of natural forces. As contrasted with primitive conditions the operation of the natural processes of selection has been checked to a marked extent. He who, by cause of disease, blindness or loss of limb, would under primitive conditions have been compelled to die is now cared for tenderly, and if need be at the expense of the present-day community. While such a person is thus removed from the *struggle for existence,* he is not removed from existence. As a group we no longer really struggle to live; our struggle is to make life richer and fuller. Our advantages and knowledge make it relatively easy to maintain life, and our toil is not with that sole aim.

Among primitive men the foremost problem of life was to live. They had no such social or mental equipment as ours. They never could far remove themselves from the direct pressure of natural forces. Their means of dealing with nature were from our viewpoint crude, undeveloped and insufficient. For the most part nature eliminated the individual who could not carry on the struggle, for the social surplus was not great enough to provide for the unproductive. Such groups were never, as are we, independent

at any time of their local environment. A failure of supplies in an area could mean for them only evacuation or death. Insurance against the disaster of the morrow was scarcely certain. In our early history the experience of the first Jamestown colony indicates what may happen to civilized men when removed from contact with the outside world, and when facing an unfamiliar environment. No primitive group ever brought to bear on their life problem the mental and social outfit possessed by these colonists. The failure of this group to meet the situation in the new land points the regular facts of primitive life.

The Aleatory Element

In this struggle for life and in their efforts to realize their interests, early men were far more exposed to the play of that factor in experience which we term chance or luck than are modern men. If chance is conceived to be that in experience which can not be figured out beforehand (including those experiences whose relations to their antecedents can not be predetermined, foreseen or controlled) it may be readily understood that in a state of primitive ignorance the element of chance was incalculably great. For early man could not foresee, control, avoid or prepare for in advance any number of things which are simple problems in cause and effect to civilized men. Without an accumulation of knowledge foresight becomes limited in range; without generalization from experience the result of effort may become a matter of speculation rather than of certainty. Normally, when a modern individual puts certain forces into operation he can, within limits, foresee the results. Early man neither knew nor understood the forces. Hence, in his struggle to live early man could do little else than make effort after effort without knowing how these efforts were to turn out.

For this condition of life primitives could make no rational accounting. That it was a fact of life none could question. Their subjection to the caprice of fortune lay in a twofold set of causes. On the one hand they possessed no accumulation of the experience of preceding generations of men. There existed very little from which there might be drawn a knowledge of the efforts and of the successes and failures of those who had gone before. Many a life emergency appeared as something to be met anew. On the other hand, this very circumstance forbade any appreciable growth of science. Without an accumulated record group experience causal relationships can not be established with continued accuracy. Sufficient evidence was lacking among early men upon which to base inclusive judgments of such relationships. Again, a laggard mental development hindered an approach to scientific understanding

of relations between causes and effects. Among primitive men there existed, therefore, a range of experience which lay outside their capacity either to control or to explain. "This was the aleatory element in life, the element of risk or loss, of good or bad fortune."[1]

Such a condition of existence called for some attention. Facing a situation in which at every turn an unforeseen and incomprehensible difficulty or disaster might arise early man strove to find a means of dealing with it. Here was an ever-present and obvious feature of the game of living. Its importance was vital to his interest; yet to deal with it he had to account for it. However, he could not rationally size up the case and then rationally seek to go about meeting it. Rather, feeling a need he struck out in vague efforts to account for his difficulties and then to deal with them.

Notions of Agency

Early man, however, had at hand a ready explanation of everything which demanded explaining. Primitive men, in general, ascribe all incidents either to the agency of men or of spirits. So that, in their interpretation of this otherwise inexplicable phenomenon of chance in their lives, they traced causation to the activity of spirits which were believed to surround. The origin and basis of primitive belief in the existence of spirits is not our problem here. The fact is that such belief prevailed; and on this set of ideas there existed for early man an entirely satisfactory explanation of the phenomena of chance. In the social organization of every primitive society, for this reason, there is to be found a characteristic response to this combination of ideas.

The primitive view confused cause and agency, holding that results were largely due not to any impersonal cause (of which there was no general conception) but to an agency of some sort. The latter idea was one with which they were perfectly familiar. Agency and cause were never dissociated in their mental processes. The inexplicable and the unforeseen were attributed to the action of some sentient personality. A concept of natural law and cause never, even dimly, developed among their ideas; active and personal forces were conceived to actuate all events. Illness and death, for example, were phenomena for which the lower cultures had no rational explanation with respect to their causes. These, furthermore, were misfortunes as great as early man might conceive; as indeed with us. Primitive groups traced both in origin to spiritual agency. The Central Australians have no idea of natural death. It is always due to supernatural causes.[2] Roscoe, writing of the

[1] Sumner, W. G.: "The Folkways," 6.

[2] Spencer and Gillen: "Native Tribes of Central Australia," 467, 477.

Umganda in Africa, says: "To the mind of the Umganda there is no such thing as death from natural causes, it is always due to a spirit or to witchcraft."[3] Similarly the Teneda of French Guiana do not consider illness and death as natural and normal. "They are always, among them, the result of an accident provoked by the intervention of a divinity or of some genii. Normally they considered they would not die even in the case of old age."[4]

In the case of misfortune of a more general character the same tendency is evinced by primitive groups; the unaccountable otherwise finds explanation by the attribution of cause to supernatural influence in the affairs of men. The Dusuns attribute "All such calamities as epidemics, failure of crops, etc., to the agency of their Gods."[5] Amongst the Siamese the anger of the "clan spirits is the fruitful cause of every disease and disaster that flesh is heir to."[6] Monier Williams declares that among the Hindus "all disease that either human or bestial flesh is heir to are personified and converted into demons, such as the demon of small pox, cholera and the various forms of typhus and jungle fever and of cattle diseases, and this idea of personifying and demonizing diseases is extended to unseasonable calamities and disasters, such as hail storms, droughts and blight, which all do duty in the devil army."[7]

The Imaginary Environment

All primitive men were convinced that they were surrounded by spirits, and that these spirits exerted an incalculable and unlimited influence upon mundane affairs. This belief and the reactions of society upon it are typically human phenomena; there is nothing akin to them elsewhere in nature. The human intellect with its capacity of forming ideas was led to interpret psychological phenomena and those of outside nature with the result that a belief in the existence of an otherworldliness was established. The very superiority of human over animal intelligence made men subject to such illusory concepts—lines of reaction which the lower animal mentalities could never have pursued. Through their reactions of this character, early men were compelled to add another plane to their physical and tangible environment. This we may term the imaginary environment—the surrounding spirits of various grades and authority.

[3] Roscoe: "The Umganda," *Jour. Anth. Inst.*, 31, 121.

[4] Delacour: "Les Teneda," *Jour. d'Ethnology et de Sociologie*, 4, 105.

[5] Evans: "Religion, superstitions, ceremonies of the Dusuns," *Jour. Anth. Inst.*, 42, 380, 381.

[6] MacGilvray: "Half Century among the Siamese," 203.

[7] "Brahamanism and Hinduism," 41.

Keane remarks that "all savages however degraded, if they are capable of reflecting at all, are compelled to think and reason about the dreams and visions of their sleeping hours and about the natural phenomena surrounding their daily existence. These they naturally attribute either to the shades of the dead or to invisible beings, superior perhaps, but still resembling themselves, some friendly, some hostile, and all entering into the normal condition of things."[8] His last phrase epitomizes the primitive view of things. Early man viewed the spirit world as a reality and as a fixed part of his life experience. Lippert comments in writing about this point that the strength of an idea lies not so much in its truth as in its vividness and the number of people who believe in it.[9] Both these conditions were satisfied in early society.

The Basis of the Cult

Men of every age and race strive to adapt to the conditions of life which they perceive or think they perceive to surround them. To avoid pain and obtain greater results with less effort is a common impulse of humanity. Primitive men in their attempts to adjust themselves to their environing situation were compelled to make allowance for a factor in environment which we no longer recognize—the presence of the supernatural forces. Accordingly, such men while meeting as best they might the demands of their tangible physical environment, felt that they could not afford to forget the demands of the world of spirits—the unseen environment.

The necessity of recognizing and making allowance for this additional factor was accentuated and made imperative by the belief that the aleatory element in life was somehow connected with it. There was the inexplicable in experience which was interpreted as due to spiritual agency, and primitive men sought to regulate the combination so far as they could. There was both necessity and attraction in attempting to do this. Necessity because angry spirits might harass and frustrate the most arduous efforts; attraction because of the possibility of something for nothing, results without labor, riches without toil, if only the spirits could be inveighed to use their limitless energies for human welfare.

With such an outlook on the problem of living early men strove for some method of dealing with the imagined environment. The effort took form in the cult. Schemes of every sort based on the spirit theory came into use, the purpose of which was to deal with the spirits. Avoidance, exorcism, prayer, propitiation, sacrifice,

[8] Keane: "The Botocudos," *Jour. Anth. Inst.*, 13, 108.

[9] Lippert: "Kulturgeschichte," I, 29.

magic, the medicine man and other institutions, the ensemble of which we call the cult, were developed as an adjustment to the additional environing situation.

Had the spirits been conceived solely as present but inactive it is unlikely that the cult would have become so prominent an institution in early societies. But, as early men viewed it, the spirits dominated the most characteristic aspect of the struggle for existence—the aleatory element. It was necessary to establish proper relationships with these agents who might hurt or help. The spirits being present and needing attention, the savage made it a part of his business in life to see that such attention was rendered. The cult became in this wise nothing more than one of primitive man's efforts to live as well as possible and arose as a regular part of the social organization for carrying on the struggle for existence. Primitive man having added to the terms of the struggle for existence could not be expected to employ an utilitarian method solely.

The Aims of the Cult

The accounts which we have of the cult objectives among uncivilized groups reveal that the agency of the religious organization was viewed as a part of the social mechanism for carrying on the business of living. Gomes states that "all the Dyak hopes to gain by his religious ceremonies is purely material benefits. A good crop of paddy, the heads of his enemies, skill in craft, health and prosperity."[10] Among the Koryaks of Siberia, "the Supreme being is propitiated for purely material reasons, such as the procuring of a food supply by hunting land and sea animals, the picking of berries and roots and the finding of reindeer herds."[11] MacDonald declares that "the Sikus, Lobos, Ijos every year make juju for the power to preserve their health, to prevent war and death, to maintain friendly relations with the traders and to bring good generally to the inhabitants."[12] The Eskimos told Rasmussen that they believed the magicians because they did not wish to expose themselves to famine and because they wished to live long. "We believe," they said, "in order to make our lives secure."[13] Such passages make clear that among primitive people the cult occupied a practical position in the life economy.

The Shaman

The reality of the spirit environment as primitive man conceived it, and the matter-of-fact way in which he accepted it and

[10] Gomes: "Seventeen Years among the Dyaks of Borneo," 204.
[11] Czaplica: "Aborigines of Siberia," 262.
[12] MacDonald: "Africana," I; 86.
[13] "People of the Polar North," 123.

turned it to his uses are conspicuously manifested in that important institution, the shaman or medicine man. His was an intensely practical function in the economic organization of early society. He provided a very essential means of adaptation as a means of approach to and control of the forces of the spirit world. So many were the features of the life of men coming within the range of chance, and hence according to early views under the influence of the spirits that it became expedient to select some one to specialize upon the matter. Indeed, there is here on the grand scale one of the first outstanding developments of the economic principle of the division of labor.

Among the Maori, the medicine man was supposed "to be able to interpret dreams, to explain prophecies, to cast out demons, to dissipate disease, and restore the body to health, to produce rain, to subdue storms, etc."[14] With the Malays, the Pawan "is a person of very real significance. In all agricultural operations, such as sowing, reaping, irrigation works and the draining of the jungle for planting, in fishing at sea, in prospecting for minerals, in case of sickness, in all his assistance is invoked."[15] Weeks says of the Congo negro that "the life of native, surrounded as he is by all these various spirits, would be intolerable, unthinkably so, were it not for his many witch doctors, who have power to control the spirits, and even to kill them."[16]

This brief view of the duties of Shaman indicates the exceeding value of his work. He was the specialist in the spiritual portion of the environment and in early society he was held to be as necessary as the blacksmith. Like the blacksmith also he was looked upon as a man who was prepared to perform a certain function a little better than any other person. If the malignant spirits were turning things topsy-turvy; if it was desired to take out an insurance policy against their future bad behavior, the Shaman was the man to whom to apply for aid. He was a public officer directing the group in its relation to its imaginary environment. His was a unique position; there is nothing like it in the story of mankind—a specialist in an imaginary field, upon whose offices it was believed that the success of the group in the struggle to live depended.

That his position in early society was regarded as practical in character is clearly evidenced in the fact that among many groups he had to obtain the desired results or lose his hold. Two citations will serve to indicate what may be shown to be quite regular among primitive groups. Among the Patagonians, Musters says "the po-

[14] Nichols: "The Maori Race," *Jour. Anth. Inst.*, 15; 199.

[15] Skeat: "Malay Magic," 57.

[16] Weeks: "Among Congo Cannibals."

sition of wizard or doctor is not a very desirable one, as in the event his prognostications on a war expedition or . . . in sickness, or any other event which is not realized, the chief will not infrequently have him killed.''[17] In South Africa, "if, unluckily, one of these magicians happens to have predicted falsely several times in succession he is thrust out of the kraal, and very likely burned or put to death in some other way.''[18] What was demanded were results—practical working results, along with dependable predictions. If a man pretended to be a specialist in the spiritual environment and in the ways of the spirits he was tested by the results of the aleatory element in the group experience.

Sacrifice

The economic attitude of the uncivilized toward the spirits and deities is revealed also in their viewpoint in the matter of sacrifices. Propitiation, of course, may from our view of the cult be regarded as in the nature of social insurance against spiritual harassment in the struggle to get along. Sacrifice was a form of propitiation in the shape of material offerings to the spirits to satisfy their supposed hunger or greed. Such offerings, however, were not made gratuitously by primitive men. They were in effect like a cash payment for service rendered or about to be received; and their quantity, quality or value was regulated by the size and the character of the service desired. A few instances will illustrate the conduct of early men in their performance of sacrifice.

Schwannhauser says of the Dschagga, "The sacrifice animals are exactly in accordance with the value of the desired-for benefit, costly or less so.''[19] That intrepid lady, Mary Kingsley, remarked, "The value of the offering in these South West Coast regions has certainly a regular relation to the value of the favor required of the spirits.''[20] A similar notion prevailed among the Homeric Greeks: "The sacrifices were in the nature of a contract, actual or implied, and in which one or both parties might be bound. In a regular bargain the sacrifice payment to the Gods was conditional upon their actual fulfilment of some request; in the other variety, the offering was made to the Gods *in the hope* that they would grant the request.''[21]

All the evidence available makes clear that sacrifices to the spirits by primitive men were payments and that no idea of renun-

[17] Musters: "On the Races of Patagonia," *Jour. Anth. Inst.*, I, 203.

[18] Lichtenstein, "Reisen im Sudlichen Africa," II, 61.

[19] Schwannhauser: "Seelenleben der Dschagga Neger," 38.

[20] "Travels in West Africa," 306.

[21] Keller: "Homeric Society," 24.

ciation obtained. The Lolos of West China with some naïve perception of the nature of the case declared that such payments were blackmail.[22] In two modes sacrifice appears as a payment. Above all it was a neutrality toll—a bit of blackmail levied by the spirits in return for which they would keep their hands off human affairs. Again, it was a payment for good services, either to be rendered, or that may have been rendered. Blackmail or bribery both were fees gladly paid by early men. In this view sacrifice becomes a matter of precaution in life's everyday affairs. It was made a business proposition, payments in proportion to returns, received or anticipated.

The Cult as a Prosperity Policy

From what has been presented we are prepared to assert that in primitive social groups the cult and the struggle for existence were closely allied. The basis of this connection lay in the nature of early man's life experiences and his interpretation of those experiences. In ignorance of causal relationships in the scientific sense, and with, on the other hand, a developed set of illusions as to the spiritual character of his environment, it was simple for him to complete the structure in the endeavor to protect his material interests and provide for his necessities. He thus, taking cognizance of the spirits, went at the need in a practical, serious manner, and with very definite views as to what he expected to gain by so doing.

There is in the facts of the cult evidence of a tremendous group reaction upon a set of beliefs which had no basis in fact, but which, nevertheless, gave rise to institutions and to practices of profound social significance. The cult represents a case of adaptation to a non-existent environment, yet which was to early man as real as any of life's tangible factors. There was very little that was ethical or religious about all this, as we use the terms. It was the material needs and interests of men which induced them to introduce the cult into daily life. Truly, the primitive cult rested on a far more fundamental basis than that of a philosophical or theoretical morality. It was regarded as an actual factor in the struggle to live, as early men saw that struggle.

Bastian remarks in one of his works "that the heavier the burdens one puts upon the negro the more fetishes will he, on his side, add to compensate for the increase."[23] This would very naturally follow from primitive deductions as to the cause of trouble and care. Indeed, interpreting the facts of life as early men did, convinced that spirits lurked everywhere, awaiting an opportunity to

[22] A. Henry: "Lolos of N. China," *Jour. Anth. Inst.*, 23, 104.

[23] Bastian: "Afrikanische Reisen," 80.

thwart and harass, it is not surprising to find the proverb of the Bechunaa, "A man may not live without charms."[24]

This view of the cult makes clear many things which otherwise might baffle. Many of the practices which engaged primitive men in the cult were expensive and ruinous in their economic effects. It may not be believed that primitive men destroyed their capital, abandoned their growing crops and their houses out of mere caprice or foolhardiness. No man or group of men ever consciously set out to harm or impede their own life's interests nor to jeopardize life nor destroy their valuable property without reason. Heavy as were the burdens which his faith in spirits imposed upon him, early man held that he was doing the expedient thing. Attributing his vital concerns to the activities of spirit agency, he could not afford, whatever the cost, to neglect the spirits. The burden was acquiesced in that heavier burdens might not be imposed.

Early religion for these reasons presents no moral tendencies. Unless indirectly, it laid no emphasis on salvation or upon social ideals. At the outset, the religious organization came into view as a part of the business of life on earth. Early religious belief did not call for formal attention on stated occasions; it was an everyday consideration. In all things men did, in every interest in life the unforeseen forces might help or harass. Viewed negatively as a means of heading off disaster and positively as a means of helping things along, the cult represents a part of the prosperity policy of primitive groups.

[24] Garbut: "Native witchcraft and superstition in South Africa," *Jour. Anth. Inst.*, 39, 30.

LANGUAGE AS A FACTOR IN HUMAN EVOLUTION

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Of the many factors early affecting the change from ape-like to man-like creatures language is commonly admitted by students of human evolution to be one of the most important. Developing language was directly affected by the developing brain, and in turn reacted potently upon that developing brain. The superiority of human speech over animal speech, remarkably diversified as this latter often is, developed simultaneously with the growing human brain, of which it was partly product, partly cause.

At the same time that those wonderful ape hands were set free from duties of locomotion, through the change from arboreal quadrupedal locomotion to terrestrial bipedal locomotion, the ape brain was becoming human brain and the ape speech human speech. In fact, the freeing and perfecting of the hands was also part product, part cause of the developing brain and developing speech.

While we feel reasonably certain of these fundamental facts, it is pleasant to go a little further and to speculate as to the locality and the environmental conditions witnessing such changes. Present knowledge seems to point that it was somewhere in central or southern Asia, possibly just north of the Himalayas, mountains which are very new, geologically speaking, which, gradually rising to great heights, cut off the humidity from the sea to the southward, and changed the dense rain-forest to the north of them into more open park-like country. Many of the arboreal denizens of that forest were forced, in consequence, either to emigrate or to change their habits of life or to perish, and man was one of the species to change his habits of life, come down from the trees, gradually fit himself to combat numerous fierce foes in the open and acquire an erect, bipedal, terrestrial mode of life, using brain and hands continually in outwitting and destroying his animal foes and his prey alike.

Wherever the place, and whatever the environmental changes or circumstances which may have aided in this most interesting transformation, the fact remains that speech became humanized contemporaneously with the humanization of the animal brain and extremities.

The language of many animal species is, however, remarkable. Any person possessing good powers of observation, and living some length of time during childhood or youth in close proximity to domestic fowls, may readily learn to understand their language, the meaning of each sound they utter. Their language is quite diversified, and really remarkably ample, especially so when you consider the stupidity of domestic fowl. Their language was developed during their wild state, and passed on, partly by word of mouth (and syrinx), partly by instinct, generation after generation, to their less intelligent domesticated descendants, of every strain, the world over. Size, color, markings, laying ability and vocal timbre have been greatly changed through human selection, but they all speak the same language which he who learns may understand. Probably it would never have been developed to its present fulness if their feral ancestors had been as stupid, and had led as monotonous, safe and humdrum a life as our familiar chickens live to-day.

Our species of birds have their distinct languages, although some species are relatively silent. Mammals also have their various languages, and the different species of apes and monkeys are no exceptions to this statement; in fact, some species are distinctly and volubly chattersome. The human being of to-day, still considered a kind of ape by some zoologists, may likely have descended from a common ancestor of some of these volubly loquacious species. Further back, of course, all species of apes and man descended from a common ancestor, and yet further back all mammals from an early mammalian progenitor.

In the light of the common ancestry of all mammals and of all vertebrates in more ancient time, it is not surprising to find that certain sounds, ejaculations and tones are common property, not only to every mammalian tongue, but hence also to every human tongue or speech. Certain sounds denoting joy, grief, fear, distrust, amity and some other feelings are used by all tribes of men and by many mammalian species, and are understood by men of every tongue, without an interpreter, and by other mammals, having been passed down, partly by word of mouth, partly by instinct, from generation to generation of early, middle and recent mammals, including man.

In the little time that man has been in existence several distinct species of man have been evolved, but of these all are now extinct but one, being numbered with the vast multitude of extinct animal species, the long list of which grows prodigiously with each year of paleontological discovery. The one remaining species of man speaks hundreds of different languages.

The magnitude, elaborateness and diversity of our languages are due primarily to our unique proficiency and versatility in linguistic lines, made possible through the special development of the brain areas having to do with speech and thought, and secondarily through the specialization of certain vocal and other structures used in speech.

The great number of different languages spoken by different groups of men is due to man's linguistic proficiency and to geographical isolation of various groups. As all speech is continually varying, the speech of each isolated settlement would vary independently of each other settlement, producing a general divergence of the language of different sections of territory. After hundreds of thousands of years of isolation, broken by migrations small and large, we are at the present moment witnessing the origin and development of worldwide intercourse, progressing with wonderful rapidity.

How will this worldwide intercourse, soon to be consummated, affect language, which, as we have seen, is very sensitive, reacting to every stimulus; and how will the resulting unified language react upon the evolution of man in the future?

Let us return first to consider, very briefly, how language affected human evolution in the past, and then turn to its effect upon human evolution in future.

When man crossed the line which separates the genus Homo from his ancestral genus, which was when a particular strain of primates became, in the course of their evolutionary changes, sufficiently human to be called human, the change was marked primarily by the enlarged brain, highly specialized in those regions governing thought, speech and manual skill. His immediate pre-human ancestors had had remarkably good brains and unusual linguistic abilities, expressing through increased speech the increasing range of thought. The earliest father, mother and children of truly human standing were not exactly college graduates, but had graduated from the sub-human grades.

In somewhat the same sense that a boy about to enter college delights to call himself a sub-freshman, Eve's mother nursing little Eve in her arms might have been called a sub-human group. Eve had not grown up yet to demonstrate that she was really human. She was only, as it were, a rib in the side of her sub-human parents. She was probably very young when she married, for the way of nature is to marry young, and was, therefore, for a while, like a rib in her husband's side; as in her inexperience and mental immaturity she gradually opened, like a flower in the sunshine, under the influence of Adam's love, speech and experience, and finally demonstrated that she too was human.

In the early human families which followed, language grew by leaps and bounds, just as worldwide communication is leaping forward to-day. Every new thought called for a new word or a new phrase to express it. But a very important fact in this connection, and one to which philologists and evolutionists alike give great stress, is that words, phrases and expressed thoughts react upon the brain which coins them, and also act upon the brains of listeners.

All the objects in the natural world surrounding animals stimulate thought in those animals in proportion to the degree of intelligence possessed by the animal. Man, being superior in intelligence, was stimulated to more remarkable thoughts by these natural objects than were his inferiors in the evolutionary scale. But the acts and vocal expressions of his living companions are equally or more stimulating to the man or other animal. As these vocal expressions became more elaborate and more intense, keeping pace with the growing intellect, they became even more stimulating, both to the men who heard and also to the man who uttered. Each more advanced expression, each well-expressed idea was a new stimulus to that remarkable brain. So language grew with intellect and intellect grew with language; hand in hand they climbed the mountain, and helped each other up many a cliff and over many a dangerous chasm.

As side by side language and mind reached greater heights, now and then there opened up to them broader and clearer vistas of the world, and, in consequence, emotions of greater depth sprang into being. New forms of expression were needed to communicate the new emotions or new shades of old emotions, and the dawn of a concept of a world above, below or beyond the visible world was imminent.

It is quite clear that language has been a potent factor in human evolution in the past. From the very earliest beginnings of human existence to the present day it has, with brain and manual skill as the other two, constituted one of the three prime factors of human evolution, factors which are the intimate possessions of man himself rather than being factors belonging to his external environment.

The fact that language has been, from man's beginning to the present, one of the most intimate and effective factors in his evolution, affords very reasonable assurance that language will continue to be a prime factor in the further evolution of man.

Great care and thought and effort should be expended on our language of the present and near future, realizing how fruitful the results in molding the man of the future. In this connection consider the two great outstanding facts, that language is most plastic and continually changing and that we are at this moment in the

midst of the movement toward world communication, travel and intercourse, which is being developed with great rapidity, which the world has never witnessed before and which is likely to last as long as life lasts on earth. These two outstanding facts mean that there will be one world language to-morrow—probably within the lifetime of many even of the older readers of this paper and of practically all the younger folk.

What shall this world-language be? It is sure to be a boon to the world in any case.

The incidents of my own life, rather unique in some respects, have been such as to repeatedly impress upon me the similarity between language and shifting sands and changing shoreline. My father accepted a diplomatic appointment in Belgium resulting in our leaving America and living in Liége during the years of my early teens. There the official language of court and school was French, but many of the common folk spoke Walloon, a distinct branch of the Romance languages with a touch of Flemish and Low German. This combination was an eye-opener to an American boy who, in addition, had to translate his Latin lessons into French, and French to Latin, and began the study of Greek in French. The servants in the house—and most excellent ones they were—were from Maestricht, just across the Holland border, and spoke no English, only Dutch, French, Flemish and Walloon, being merely uneducated servants. After several years of this life we spent a whole year in travel and study in Germany, Switzerland, Italy, France, Holland and Great Britain. Later, in trips to Canada and the French, British and Spanish-speaking West Indies, and, shortly many before the war, to Triest and the Karst Mountains in Austria, where languages literally by the half-dozen were on the tips of the tongues of the shop-keepers in every little store and dairy, I received ever new impressions of the endless variety and constant shift of the sands and tides on the world's linguistic shore. In Zürich I was told by an official in the forestry school that there are more than twenty distinct dialects in the German-speaking part of Switzerland alone, due, of course, to natural barriers in that rugged mountainous region. At present it happens that while most of my work requires the use of English, I also have to use some Spanish daily. A trip all over the world would ring endless permutations on the same theme, that language is like soft clay, being molded by factors within the man and in his surrounding environment, yet all the while reacting upon the man and his fellows. Languages come and languages go, but life goes on forever.

What shall the world-language be? Emphatically English, simplified and spelled phonetically, For some years it has been evi-

dent that English might become the world-language, but very recently it has come to appear almost inevitable. Men whose business interests encircle the globe are realizing this fact in advance of the rank and file.

English is spoken all over the United States, the most influential republic in the world. The British Empire includes well over one quarter of the land surface of the globe. Australia is about the size of the United States, and Canada is larger. The vast Indian and African possessions of the British will probably be English-speaking territory before long, and already, as the language of commerce, English is in advance of other languages. The people of China speak dialects not understood in all parts of China; their postage stamps are printed in Chinese and English. With the exception of some very small areas in which peculiar varieties of English are spoken, English is the same all over the English-speaking world, with only minor differences in accent and vocabulary, so that practically all English-speaking people understand one another without difficulty; which can not be said of most widely-spread languages.

English as a world language should be spelled absolutely phonetically to fit it for the use of continental and other people, as well as to simplify it for our own children. The changes in spelling should be no more radical than is absolutely necessary, yet wherever a radical change is imperative it should be in the direction of continental spelling. The number of different vowel sounds should be restricted, avoiding super-refinements in the pronunciation of different words when possible. The changes in spelling should be as few as possible, yet they should be sufficiently radical to make the rules of pronunciation very simple and so few that any one could become familiar with them in ten minutes. This will avoid the necessity of memorizing long lists of newly accepted spellings.

Without presuming to offer the following scheme of spelling to the world as its future language, I present below a simple illustration of the above-mentioned principles. It is offered simply as an example of what seems to be the simplest and easiest way for all people to spell English. The English language has some very strong advantages over other languages, as its simple treatment of the verb, its strict confinement of the masculine and feminine genders to things which are truly masculine or feminine, all other things being neuter, its splendid literature and the all-conquering aggressiveness of the English-speaking peoples.

a to represent 2 sounds: a as in cat, mat; ā as in are, Arlington, bar (ār, Ārlington, bār); replaced by o when having the sound o in or, lord: walk, awful, all, are ouc, oful, ol. The sound of ai in pair, air, is represented by

e: per, er. The sound of ai in pail, fail, is represented by ē: pēl, fēl. The sound of a in pale, tale, also represented by ē: pēl, tēl.

e to represent 2 sounds: e as in met, set, let; ē with the sound of ai in pail = pēl; to be omitted, 1. when silent, 2. when having the sound of e in er in butter, ermine, = bŏtr, rmin, 3. in final ed when not distinctly pronounced: sliced = slaisd, but sounded = sāunded, omitted = omited. *ee* pronounced as at present: meet, meat, sweet, are meet, meet, sueet.

i to represent one sound as in it, sit, fit; when sounded as in kite it is really a double sound, to be replaced by ai: cait, the personal pronoun I = ai, not egotistically to require a capital except when beginning a sentence.

o to represent 3 sounds: o in or, lord; ŏ in mŏnth, cŏvr, lŏvr; ō in clōvr, ōvr; replaced by ā when pronounced as in not, knot, how, cow, = nāt, nāt, hāu, cāu. oo as in boot replaced by *u*, but.

u to represent 2 sounds: u in true, blue, impromptu, = tru, blu, imprāmptu; ŭ in put, full, = pŭt, fŭl; preceded by i when pronounced as in cute = ciut, a double sound.

w and *y* are not needed. Every silent letter omitted. Consonants not doubled. Hyphenated words made compound by dropping the hyphen.

c hard; replaced by s when soft.

ch as in church; replaced by c when hard, and by *sh* when so sounded: chimney, chemistry, chemise, = chimnee, cemistree, shemees.

f as in fit; replaced by *v* when so pronounced: of = ŏv; replacing gh when so pronounced: rough = rŏf.

g hard; replaced by j when soft.

ng as at present: sing. *k* and *q* not needed. *r* as at present.

s as at present, and replacing soft c, but replaced by *z* when so pronounced: is = iz. *sh* as at present, and sometimes replacing ch: chemise = shemees.

t as at present, but replaced by ch when so pronounced: substantial = sŏbstanchal.

x as at present, but replaced by *z* when so pronounced.

z as at present, and replacing s and x when these are so pronounced.

More examples: "Though the rough cough and hiccough plough me through," would read "tho thee rŏf cof and hicŏp plau mee thru." "Xenophon knows how to play the xylophone but prefers the flute;" Zenōfōn nōz hāu tu plē thee zilōfōn bŏt preeferz thee flut. At present he receives six per cent. on his money; At prezent hee reeseevz six prsent ān hiz mŏnee.

The Lord is my shepherd, I shall not want. He maketh me to lie down in green pastures; he leadeth me beside the still waters; he restoreth my soul.

Thee Lord iz mai sheprd, ai shal nāt uant. Hee mēceth mee tu lai daun in green paschurs; hee leedeth mee beesaid thee stil uoters; hee reestoreth mai sōl.

Whoever helps the spread of English as a world language will aid world inter-communication and hasten human evolution. Whoever helps to refine the language by using the choicest and most beautiful expressions and words, and avoiding consistently all cheap, foul or vulgar expressions, will aid in guiding human evolution in the right direction, since language continually reacts on the speaker and hearer.

JOHN T. GULICK, A CONTRIBUTOR TO EVOLUTIONARY THOUGHT

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ONE more of our few remaining ties with the initial period of Darwinian thinking was severed by the death of Dr. John T. Gulick, on April 14th, 1923. He was born in the Hawaiian Islands in 1832, the son of a missionary, and his early years were spent in that region. As a youth he travelled in Oregon, dug gold in California and visited the Gilbert and Caroline Islands. Among the papers he has left is a very unique diary of these experiences, in which can be traced the development of his intense fondness for natural history. It was his good fortune to become acquainted in 1853 with Darwin's "Voyage of the Beagle," and with Hugh Miller's "Footprints of the Creator." He was greatly impressed with Darwin's description of the localized species of birds and reptiles in the Galapagos Islands, and at once began to make comparisons between the facts which Darwin presented and facts that he could observe for himself in his own islands. Hugh Miller's book was a presentation of the main outline facts of paleontology, together with an exposition of the principal theories of evolution previous to Darwin, and an argument intended to refute evolutionary doctrines.

Under these influences he devoted his major energies during 1853 to systematic and thorough collecting of the land snails of the Island of Oahu, Hawaii. The conviction had grown up in his mind that written upon the very form and structure of these Hawaiian shells was a marvelous self-revelation from the hand of the Creator Himself, and that if we could but learn the alphabet we might read from them the story of his method of creation.

John Gulick had selected foreign missionary work to be his life profession, following the example of his father. He prepared himself in Williams College (class of 1859) and in Union Theological Seminary, and then found his way in 1862 to the Orient. The first two years he was in Japan, a country that was hardly yet really open to foreigners. After that he was stationed in North China until 1875, and from 1875 to the time of his retirement in 1900 he was a member of the Congregational Mission in Japan. The last 17 years of his life he resided in Honolulu.

Gulick was one of the small group of Americans to be promptly and completely convinced by Darwin's argument when the "Origin

of Species" first came into their hands in the winter of 1859–60. And, indeed, the broad concept of evolution through descent was but an easy step forward from the opinion towards which he had already been inclining for several years that "many genuine species had been derived by descent from one original stock or species." But he did not feel that all the problems had been solved, and throughout his whole career he spent much thought in analyzing his data from Hawaii. The first published fruits of this analysis are found in *Nature,* July 18, 1872 ("The variation of species as related to their geographical distribution, illustrated by the Achatinellidae") and in the *Journal* of the Linnean Society, London, Vol. 10, 1872 ("Diversity of evolution under one set of external conditions"). Further contributions were published in the same journal in Vol. 20, 1887 ("Divergent evolution through cumulative segregation") and in Vol. 23, 1889 ("Intensive segregation"). His most serious presentation of the whole subject is the book, "Evolution, Racial and Habitudinal," published in 1905 by the Carnegie Institution of Washington. A number of minor papers appeared from time to time in *Nature,* the *American Journal of Science,* and the *American Naturalist.* Of his papers on other subjects, religious, linguistic and the like, we need only mention here his article on "Christianity and the evolution of rational life," appearing in the *Bibliotheca Sacra* for January, 1896, in which is published the correspondence upon the subject of religion which he had with the English zoologist, G. J. Romanes.

The contributions which Gulick made to evolutionary theory had their starting point in his observations upon the land snails of the Hawaiian Islands, and more particularly the forms found upon Oahu, the island on which Honolulu is located.

The great bulk of the Hawaiian snails belong to a family not found elsewhere. Although broadly related to each other, they are divisible into two or more sub-families possessing a number of genera and a host of species. The majority of them live in the leaf mould of the perennially damp forests, and are able, in a limited way, to travel about over a forest area. But contrasted with these is one whole subdivision, the Achatinellidae, the species of which all have their permanent abode at a higher level above the ground, upon the trunks, branches and leaves of the forest growths. The very numerous species of this beautiful group are quite diverse in size, shape and shell texture, and are besides decorated with brilliant hues of green, pink, red, brown, black, straw and porcelain white, laid on in variegated patterns of spiral bands and flame marks. As compared to other land snails they are fairly active creatures, apparently rather short-lived, and probably fairly rapid

reproducers. In their natural haunts they cull their nourishment from the thin film of algae and fungi on the bark over which they wander. But they are not squeamish feeders, and in laboratory they will eat liberally of almost anything that has the right physical consistency—banana peel, for example, or even wet paper.

These Achatinellidae have their power of migration limited to a very extraordinary degree by their special manner of life. They are never seen coming down and crawling across from one tree to another, as the garden helices do in Europe. They bear living young which are able to cling to the trees from the start, and take care of themselves in much the same manner as when adult. They do somehow spread themselves from tree to tree, and have even become abundant in some places on groves and thickets of foreign plants, such as the guava, that have been rather recently naturalized. But still their power of dispersal is so slight that when a tree falls to the ground, the greater part of its snail colony appears to perish along with the mouldering log.

The forest belt in which they are distributed is not continuous, but consists partly of small groves and isolated thickets located in the brook gulches on the sides of the mountains, and partly of the dense tangled shrubbery of the higher summits, separated from each other by precipices and knife-edge divides. The lowlands into which the brook valleys open out have neither the trees nor the moisture to support an Achatinella. A strip of grassland or a well-developed escarpment can produce as complete an isolation among these snails as would be caused for most animals by a continental range of mountains. But while animal populations on opposite sides of the Alps or the Rockies may be expected to face different environments through the diversity of climate and of food plants, the isolated colonies of these snails, separated perhaps by only a quarter mile of treeless ridge, or a half mile gap of grassy lowland, were certainly living under practically identical environments in all their different groves.

Gulick saw in this as it were an experiment, performed by Nature herself, to demonstrate what would happen in the evolution of a species, if it were broken up into little colonies, each of which was closely isolated in its own little precinct, where its environment was just about like that in all the other precincts. Darwin had shown that the environment, by selecting the individuals that best fitted it, and eliminating the rest, would exert a sort of outside compulsion, forcing all the animals in one environment to evolve in one direction. But the actual evolution of the snails in this great natural experiment had been in diverse directions, proving that there is more happening in evolution than the factors discovered by Darwin can account for.

Speaking to a Honolulu audience at a comparatively recent date, Gulick said:

> Each valley on Oahu was occupied by some peculiar forms. Valleys only a mile apart were occupied by distinct varieties, and sometimes different species. Groves of the kukui [or candlenut tree] in valleys five or six miles apart were found to be the homes of completely separate sets of species. Standing on Roundtop [a hill which overlooks Honolulu], I could say, in this valley of Makiki, on the west side of this hill, is the birthplace of *Achatinella producta* and *Achatinella adusta;* and in Manoa, on the other side of the hill, were created *Achatinella johnsoni* and *Achatinella stewartii;* while a mile to the northeast, in the jungle that clings to the almost precipitous cliffs on the other side of the backbone of the island, is the home of the very rare and beautiful species *Achatinella versipellis.*

Had he chosen, Gulick might next have transferred himself in thought to some other hill two or three miles distant and pointed out other equally striking assemblages of forms. The most noteworthy spot is perhaps the north west wall of Nuuanu Valley, a short distance back of Honolulu, where C. Montague Cooke has studied the close localization of 25 color varieties of *Achatinella vulpina* in the different parts of a collecting belt that extends only about one mile, with a width of 100 to 400 yards.

In general every grove has a considerable variety of color patterns, and some variability in size, shape and texture. Neighboring groves reduplicate a share of these patterns, but are likely to introduce some new note. Groves further along have progressively more and more such new notes, and fewer old notes. Some of the color patterns are relatively persistent, ranging over the groves of several entire valleys; others are so local as to be known only from a single "pocket" or cluster of trees.

Another prominent fact is the breakdown of the old concept of "species," when applied to the Hawaiian snails. It is a familiar thing nowadays that in young, rapidly evolving genera of plants and animals no one can say categorically, "These two forms are varieties of one species, but those two forms are two distinct species." On the old theory that each species was separately created, it was supposed that no such separate creation would intergrade with any other species, and the absence of such intergrades was looked upon as one of the necessary criteria for "good" species. But if species are merely varieties which have grown away from each other till it is no longer fitting to call them the same, then there can be no such simple way to define the moment when they cease to be "the same" and become "different." Incipient species of a rapidly evolving genus are likely not only to be bewilderingly similar, but also to further confuse the classifier by presenting intermediate forms that link all the different species to each other.

In a few cases a particular species of *Achatinella* seems to be well marked off from its nearest relative, as a result of the extinction of the varieties that must have been in the intermediate valleys lying between it and the home of its nearest relative. Supposing we willfully extended this process of exterminating the intermediate colonies by burning out a couple of miles of forest here and there, we would certainly be increasing the number of separate groups of forms that were free from intergrades, and making it easier for the systematist to define these "species." But surely the number of kinds of snail is quite as great before the destruction as after. Gulick often spoke of this proof of the breakdown of the old species concept. In his own naming of species he gave different names to any forms that seemed to differ with a fair degree of constancy, and those less numerous individuals that bridged the gaps between the more abundant and important typical forms he frankly designated as intergrades or connecting links.

These commonplaces of modern biology were not recognized in 1850, and Gulick was among the first of scientific zoologists to observe them in actual wild life.

The information gained in the last quarter century regarding laws of heredity has thrown these early observations into a somewhat different perspective, but I believe without diminishing their importance. In particular, people of the 19th century were inclined to assume that cross-breeding of two forms produced offspring with an intermediate appearance. We now know it is possible for the mixed population to be devoid of intermediate examples, and composed entirely of individuals that appear to be uncontaminated examples of the one or the other parental stock. Applying this to the Hawaiian snails, when Gulick observed in Manoa Valley the two contrasted forms, *Achatinella johnsoni*, with its incisive and reasonably constant color pattern of very dark and light spiral bands, and *Achatinella stewartii*, in which the broad ground color of buff or brownish green is only interrupted by one narrow line of darker pigment, it was impossible for him to consider them the same kind of snail. Sorting them into piles it is instantly obvious that they are two definite and different things. But collectors on the grounds to-day know that wherever *johnsoni* is found, it lives together with *stewartii* as a single indivisible population. It seems likely that they differ from each other by factors that are inherited in an alternative, that is to say, a more or less Mendelian manner, and so, although the student of evolution must continue to think of them with their differences, he must approve of the systematist's action in denying to *johnsoni* even the dignity of a variety in the taxonomic sense. This is just an illustration. Many of Gulick's "species" are nothing more nor less than out-

spoken color forms which a person might perhaps develop into "pure lines" by laboratory methods, but which do not exist in nature as self-maintaining populations, and very likely never did. The genetic formulae of none of these forms have ever been worked out through experimental breeding, but if this is ever done, the formulae for color and pattern inheritance will probably be very complex.

It is worthy of note that although so many of Gulick's old "species" are now called "varieties," "mutants," "color forms," etc., the assemblages that are still regarded as "species" by the modern taxonomist have an extremely local range. The Koolau Mountain Range on Oahu Island, for example, although only about 30 miles long, has 14 species of the subgenus Achatinellastrum alone, each with a geographical extent of from 2 or 3 up to some 12 miles. The average distance between the easternmost and westernmost colonies of each species is only about 6.5 miles. Each of the other subgenera would tell a similar story.[1]

Taken all together, this snail fauna is more suggestive of a diminutive continent than of an ordinary island. Imagine a mountain range 1,000 miles long, supplied with an ordinary fauna of snails—some of its species distributed along perhaps a third of the length of the whole mountain chain, but a good many local species spread to cover scarcely farther than one tenth of the chain. Then imagine these mountains shrunk till they extended only 30 miles, everything still to scale, so that every 100 miles of the original is now represented by only 3 miles, and imagine that every species of snail inhabits only the miniature district which this process leaves for it, and you will then have a very good picture of the chief mountain range of Oahu, with every little ridge and valley occupied by some distinctive and absurdly localized form of snail.

The cause of all this multiplicity could not be the external environment, because a uniform cause can not account for diversity of evolution. So by elimination Gulick concluded that the snails must be showing a spontaneous tendency to change their average characteristics, and that in no two colonies did this tendency lead in exactly the same direction. Where great numbers interbreed as a single population there might be many such tendencies represented, but a large share of them would be neutralized by the intercrossing of opposite traits. But in a little group of individuals there could not be so many tendencies represented by the limited number of reproducing parents, and whatever tendencies happened to be on hand would be far likelier to reveal themselves unhindered by crossing with any reverse tendency. Thus a big compact popu-

[1] See H. A. Pilsbry, "Manual of Conchology," Vol. 22.

lation does not quickly change the average of its characteristics, while isolated colonies numbering only a few individuals apiece have an unlimited opportunity to blossom forth into any novel form towards which their unstable heredity may trend.

So the unusually extreme subdivision of this land snail population into tiny, closely isolated colonies opened the way for an astonishing display of the inherent tendency to vary progressively in sundry directions almost without limit, a tendency that is universal among living creatures, but is generally held in check by free intermingling. This led Gulick to place great emphasis upon every form of isolation or prevention of mingling, and also to emphasize the great significance for evolution of many factors that are of internal origin, such as the unknown intricacies of the process of heredity, and the effects of new choices made by the evolving creatures, which may lead them into new situations and subject them ultimately to an entirely altered trend of natural selection.

In his largest work, "Evolution, Racial and Habitudinal," Gulick followed a somewhat formal dialectic treatment by which he could make a technically exhaustive enumeration of the factors of evolution. This manner of treatment is a little foreign to the average scientist to-day, but it has its own great value, particularly as a method of mapping out the whole field of the subject, and making obvious in what portion of the field to look for new scientific discoveries.

He pointed out a limited group of conditions that every sexually reproducing species of plant or animal must fulfill in order to be broken up by evolution into a diversity of species. Obviously its reproductive power and ability to survive in its surroundings must be sufficient to keep it from being exterminated. But also it must have what we call heredity—the power to maintain the essentials of its type, and variation—or the tendency for individuals to show tentative changes in the hereditary type. To these points, which every evolutionist admits, Gulick added those which constitute the essence of racial segregation—the breeding of like with like, to the exclusion of others which are unlike, or which are on the road to become unlike. The factors in this racial segregation, he analyzes as, firstly, the different forms of isolation (of which geographical isolation is the simplest, most obvious illustration) and, secondly, the different forms of unequal survival, such as natural selection. When natural selection intensifies the initial differences between two segregated populations, he calls the result intensive or cumulative segregation, the outcome of which is divergent evolution.

But transformation of race is not the whole of evolution. Civilization also evolves, and in lower animals there is an evolution of

habitudes, that might be viewed as a rudimentary counterpart to the evolution of civilization. Gulick points out that this habitudinal evolution is exceedingly important, because it is perpetually changing the trend of natural selection, and thus influencing the direction taken by racial evolution. His tabular review of habitudinal evolution has much similarity to the racial. In place of reproduction is here the power to obtain imitators or pupils. Tradition is the counterpart of heredity, innovation or inventiveness the counterpart of variation. Segregate association here plays the corresponding rôle to segregate breeding (or racial segregation). And, finally, to the cultural analogs for selection and survival he gave the names of election and success.

The only factors in divergent evolution that he worked out in detail were those that have directly to do with segregation. Even selection, although it is one of the great causes that intensify segregation, no longer needed an exhaustive presentation, after the controversies that had centered about it ever since 1859. And as for heredity and variation, so little was known at the date of his writing —the rediscovery of Mendel's laws came just as Gulick was beginning to prepare his book—that he judged it much the soundest plan to leave their principles practically undiscussed. He did not join in the controversy about the "inheritance of acquired characters." When he used the term "acquired characters" he almost always meant the changes in skill and in tastes that come from habit, education and the like. This variety of acquired characters he discussed repeatedly in their relation to habitudinal evolution. Mendelism interested him intensely, but he felt that it comprised a research field for the younger generation rather than a topic for his own discussion.

The careful reader of Gulick's book on evolution will note a continual emphasis upon the spontaneous or "voluntary" activities of the evolving animals, and at the top of the evolution series a stressing of the evolution of social and moral qualities, including those most remarkable and supremely important phases of human evolution, the development of altruism, cooperation and regard for the general good. In his last years this aspect of evolution and its practical application to human affairs claimed his interest above all the other phases. Every person will recognize that in this practical field there will be the greatest conceivable diversity in the opinion even of those evolutionists who hold closely similar views regarding the forces at work in biological evolution. Gulick's expressed belief was that the outstanding practical problems in the evolution of civilization to-day are the development of the principle of cooperation, of genuine equality in the opportunities for accomplishment,

and the establishment of motives for serving the community that will be less antisocial than are the selfishly competitive motives which too often rule in these days. He believed further that the world is practically without any political group that is seriously grappling with the last of these problems, and that the State Socialists are the only party with any reasonable solution of the first two points—indeed the only ones (unless it be the communists) to have attempted any answer at all. Some of his latest articles deal with his thoughts on this problem.

In these days of supposed conflict between religion and modern science it is worth recording that throughout his life the motives that inspired Gulick to study the processes of evolution were always deeply religious. It was in a spirit of loyal reverence for the Great Creator that he sought to learn something of the process of creation that is still going on. And it was always with a thrill of awe that he contemplated any great valid generalization, whether it be in biology, social science or mathematics. As a missionary his reputation as a constructive scientist was his greatest asset, since it won for him a degree of respectful attention from the highly educated Japanese that they would otherwise seldom give to a religious teacher.

In his lifetime John Gulick spanned one of the world's greatest periods of conflict between modern science and the reactionary exponents of ecclesiastical dogma, yet he never lost the sense of harmony between scientific truth and religion, and he inspired many other men with the same sense of harmony.

THE GROWTH OF THE TELESCOPE[1]

By Major WILLIAM J. S. LOCKYER
DIRECTOR, NORMAN LOCKYER OBSERVATORY

I PROPOSE to-night to give you a brief history of the development of the astronomical telescope. The story is a very long one, but I hope in the short time which I have at my disposal to make you acquainted with at least some of the main features of the progress.

I want you first to picture to yourselves living in the beginning of the year 1608, that is 315 years ago, or about ten generations ago. At that time telescopes did not exist. When you looked out at the night sky you would see the stars, as you do to-day, of various brightnesses, and occasionally the moon exhibiting different forms. A more careful look on consecutive nights would indicate to you some bright star-like bodies or "wandering" stars, which change their positions with reference to other stars, and which thus behave quite differently to the stars in general. By day you would see the sun and sometimes the moon also.

If you wished to study these bodies all you could do would be to observe their motions in relation to each other. You could see nothing of their details.

The main work of astronomers before the year 1608 was therefore concentrated on observing and recording the positions of the heavenly bodies from day to day and from year to year. And this was all.

With regard to the importance of recording the positions of the stars, the planets, the moon and the sun there is no question, because it was only by knowing their positions at some epoch that their subsequent relative changes could be determined. Thus, for example, we can forecast very accurately to-day the eclipses of the sun and moon, occultations of the stars, etc.

Again, by the knowledge of star positions accurate determinations can be made of the exact position of any spot on the land or sea, so leading to the formation of a very precise map of the earth's surface.

Observations of this nature led up to the formation of ideas about the celestial system, and it was by means of these that it was discovered that the earth rotated on its axis, that the earth revolved round the sun, that the planets revolved round the sun, that the moon revolved round the earth, and such like fundamental facts.

[1] Address delivered before the Royal Institution of Great Britain on April 20, 1923.

The early observer of the night sky would have noticed that in mid-latitudes there were some stars which never rose or set, but which moved round a point in the heavens known as the celestial pole, while others rose and set, only portions of their daily paths being visible.

To determine the position of any star he would have to measure its angular distance from the pole (North Polar Distance) or from the celestial equator (Declination), and also its angular distance from a plane passing through the celestial pole and a fixed point on the celestial equator (Right Ascension). Another method would be to measure the angular distance of the star from the horizon (Altitude), and its distance from the meridian or plane passing through the Zenith and true north and south points (Azimuth), together with the time of observation.

The early (1587) instruments for observations of position took the form of graduated quadrants mounted in a vertical plane capable of rotation about the center of a horizontal divided circle. The direction of a heavenly body could only be indicated by pointing at it, so every quadrant was furnished with a pointer pivoted at the center of the quadrant. The adjustments of the instruments were made by using a plumb line for the determination of the vertical and a level for placing the azimuth circle horizontal.

Tycho Brahe, the famous Danish astronomer (1546–1601) constructed many elaborate instruments of this nature for his observatory at Uraniberg, but his most important instrument was the large quadrant fixed in the meridian with which he observed transits of the heavenly bodies through a hole in the south wall. This instrument was the forerunner of the modern transit circle.

The telescopic era commenced in the year 1608, when, so history relates, an apprentice of Lipperhay, a spectacle maker at Middleburg in Holland, accidentally placed a double concave lens between his eye and a double convex lens. Observing the weathercock of a neighboring church he found that the object appeared magnified and upside down. Lipperhay, grasping the novelty of this lens arrangement, mounted the lenses in tubes, thus making the first telescope, and placed the instrument just at the door of his shop to amuse his customers. The Marquis of Spinola, then at The Hague, bought this "optik tube" and presented it to the Archduke Albert of Austria, and it was chiefly in this way that the news of the invention spread abroad.

Galileo, who was in Italy, hearing of the discovery, proceeded in the following year to make one himself, magnifying seven times. Galileo was the first to use the "optik tube" for the study of the heavenly bodies, and in consequence made a series of important

discoveries with his tiny telescope. Thus he found that the number of stars was enormously increased, the "wandering stars" were really planets, the moon displayed mountains, Jupiter possessed a family of satellites, Saturn exhibited curious features which were eventually identified as a ring system, Venus appeared as a crescent, spots were visible on the solar surface, etc. His discoveries altogether strongly supported the system of Copernicus.

The lens combination employed by Galileo underwent changes as time advanced. In 1620 Kepler suggested the use of two double convex lenses, and this was actually carried out by Scheiner in 1637.

One had to wait nearly a hundred years before Chester More Hall in 1733 put forth the idea of making an object glass of two different kinds of glass, crown and flint, placed close together, thus establishing the so-called "achromatic lens." It was not, however, until another quarter of a century had passed that John Dollond in 1758 rendered this discovery effective, thus heralding the dawn of what may be termed modern astronomical observation.

In the year 1639 the discovery of another form of telescope was made—namely, the reflecting telescope—but it was not until the year 1663 that the principle was described in practical form by James Gregory. It was left, however, to Sir Isaac Newton in 1668 actually to construct an instrument of this nature, and the telescope he made, which is quite small, is to-day in the rooms of the Royal Society of London.

Like the refracting telescope, the reflecting telescope underwent various changes in the optical train; thus we have the forms now known as the Newtonian, Gregorian, Cassegrainian and Herschelian.

As soon as the refracting telescope became a practical instrument it was at once brought into commission for instruments employed in the measurements of the positions of the heavenly bodies. In fact, it at once replaced "pointers."

Tycho Brahe's great quadrant was soon superseded by a type of instrument similar to that made in 1770 by Sisson for the Kew Observatory. This was an eight-foot quadrant, mounted in the meridian, with a finely divided scale and vernier. The quadrant form later developed into a complete graduated circle read by several microscopes after the type of Gambey's mural circle made in 1819 for the Paris Observatory.

The acme of perfection in accuracy is reached to-day by such an instrument as the present Cape Observatory transit circle. In this the telescope has an objective of six inches aperture of the finest construction, two very finely graduated circles are attached and several micrometers are employed for reading each circle. Many

other refinements, too numerous to be mentioned here, are included to attain the highest accuracy.

In order to follow the developments of the two kinds of telescopes—namely, the refractors and reflectors—it is best to deal with each kind separately, so the former type of telescope will be first considered.

Returning to the epoch many years before John Dollond made the achromatic lens effective, it was found that an object glass, which then consisted of a single lens only, formed images at the focus which were highly colored and spoiled definition. The only method of securing greater magnifying power, with increase of aperture or diameter of lens, was to make the lenses of great focal length, for experience had shown that the greater the focal length the less the color.

Thus, about the year 1680, we come to the age of giant telescopes, when their lengths measured anything from 60 feet to 210 feet. These cumbrous instruments were generally suspended by their middle from tall masts or towers, and to reduce their weight diaphragms placed at stated intervals took the place of wooden tubes. Thus were the telescopes of Hevelius. Huyghens adopted the novel principle of only placing the object glass on the mast, the eyepiece being attached to it by a long cord, which could be stretched tight and so make the proper optical alignment.

An illustration of a giant observatory of Hevelius' time given here (Fig. 1) displays three of these long telescopes in use. Mechanism is shown by which not only can the telescopes be hoisted into position, but which is capable of turning round the roof of the tower to which the telescopes are suspended to neutralize the earth's motion. The illustration shows that even in those days a considerable observatory staff was necessary.

There is no doubt that a telescope can not be properly manipulated unless it is equatorially mounted—*i.e.*, mounted on an axis inclined to the latitude in which it is used. One of the first, if not the first, telescopes to be set up in this manner was that used by Scheiner in 1618 for observing the spots on the sun. Scheiner had only to direct the telescope to the sun, and fix it in declination, when the diurnal movement could be compensated by simply moving the telescope westward by hand. The form of mounting he adopted was the foundation of the German type of mounting telescopes, to which reference will be made later.

Not only is it imperative for a telescope to be equatorially mounted, but it must also be driven by some power, clockwork or otherwise, so that the object under observation will always remain in the center of the field of view of the telescope.

Hooke, so far as is known, was the first to adopt this principle in 1674. As is indicated in an old print of his instrument, he mounted his quadrant at the upper end of a long polar axis, and rotated this by means of gear wheels actuated by a falling weight. The speed was controlled by a conical pendulum governor, which could be shortened or lengthened at will.

We had to wait, however, until the year 1823 before a really efficient driving clock was applied to a telescope. This was the work of Frauenhofer, and adapted to the 9½-inch Dorpat refractor, made for the Czar Nicholas of Russia, the largest refractor of that period.

The principle is the same as that used to-day: the clockwork driven by weights, and controlled by a governor actuating a tangent screw, which is in gear with the threads cut in the circumference of the driving circle, to which the telescope can be clamped.

The Dorpat instrument may be said to be the first real modern refractor, as it embodied all the fundamental features of telescopes constructed afterwards.

The refracting telescope having reached this efficient stage, a rapid survey only is necessary to indicate the growth, as this depended simply on the capacity of opticians in making large object glasses.

Reference may first be made, however, to the methods of mounting telescopes in general, because not only do the completed instruments look very different, but some forms are more convenient than others for certain purposes.

There are three well-known recognized forms illustrated in Fig. 2, and termed the "English," "German" and "Composite" types.

In the "English" type the telescope tube is mounted directly on the polar axis midway between the supports of this axis, and being symmetrically placed balances itself both in Right Ascension and Declination. The "composite" type is rather similar to that of the "English," only the tube is placed on one side of the polar axis, and the counterpoise weights on the opposite side. In the "German" type the tube, with its counterpoise weights, is fixed symmetrically to the prolongation of the upper end of the polar axis—that is, outside the supports of this axis. There is still a more modern modification of the "German" type, in which the polar axis is prolonged at its upper end, taking the shape of a fork. The telescope tube is placed symmetrically in this fork, thus obviating the necessity for counterpoise weights.

Coming now to the advance in telescope construction, time permits one only to *mention* such instruments as the 15-inch Pulkowa (1839), by Merz and Mahler, the 16-inch Harvard (1847), also by

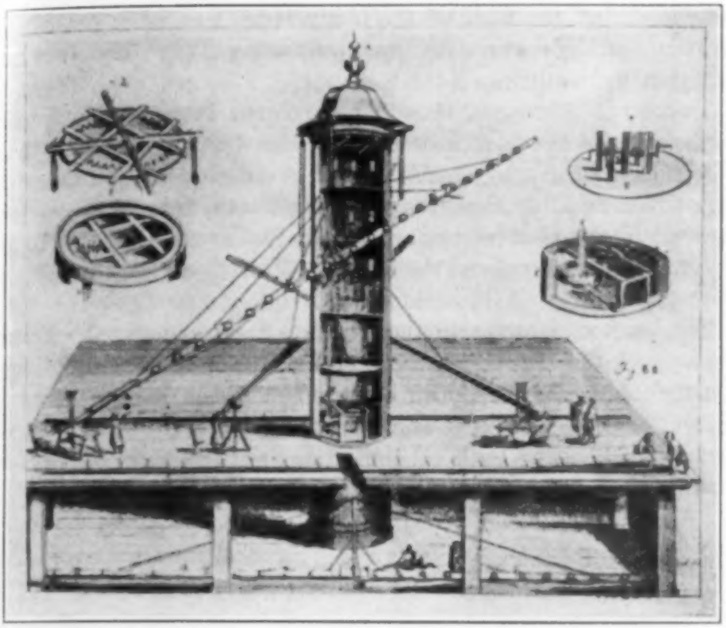


FIG. 1. HEVELIUS' AERIAL TELESCOPES
Mounted by suspension from the roof of a tower, which can be rotated by gear-work.
[From Hevelius, "Machina Celestis."]

Merz and Mahler, and the 18-inch Chicago University telescope (1862), by Alvan Clark.

The year 1868 saw the completion of the fine 25-inch made by Cooke for Mr. R. S. Newall's Observatory at Gateshead. This instrument, by far the largest of its day, was mounted after the "German" form. It had a focal length of 30 feet, so that the dome and observing chair had to be of great proportions. So satisfactory was the behavior of this instrument that, after a journey to this country to inspect this telescope, the representatives from the Washington Observatory ordered a 26-inch of 32 feet focal length from Alvan Clark, which was completed in 1873.

In 1880 Grubb surpassed this size by making a 27-inch for the Vienna Observatory, but five years later (1885) Alvan Clark turned out a 30-inch objective of 42 feet focal length for the Pulkowa Observatory. The following year (1886) saw another objective of the same size constructed by the Brothers Henry for the Nice Observatory, but this was soon eclipsed by the completion in 1887 by Alvan Clark of the Great Lick Refractor of 36-inch aperture and 57 feet focal length, erected on Mount Hamilton, in California.

For this instrument an observing chair, as such, had to be

abandoned, but the floor of the observatory was made capable of elevation and depression, thus sweeping away many difficulties and adding many facilities.

Two large telescopes, though not records in size, followed the construction of the Lick instrument. The first was the 28-inch of 28 feet focal length by Grubb (1893) for the Greenwich Observatory, mounted after the "English" fashion. This is the largest refractor in this country to-day. In the following year (1894) the Brothers Henry completed the 32-inch 53 feet focal length telescope for the Astrophysical Observatory at Meudon, near Paris.

The largest refractor in the world to-day—namely, the Yerkes telescope of the Chicago University—was completed in 1895, the object glass, by Alvan Clark, being 40 inches in diameter and of 62 feet focal length. It is mounted very similarly to the Lick instrument, and fitted with all the latest facilities for assisting the observer at the eye end, including a rising and falling floor.

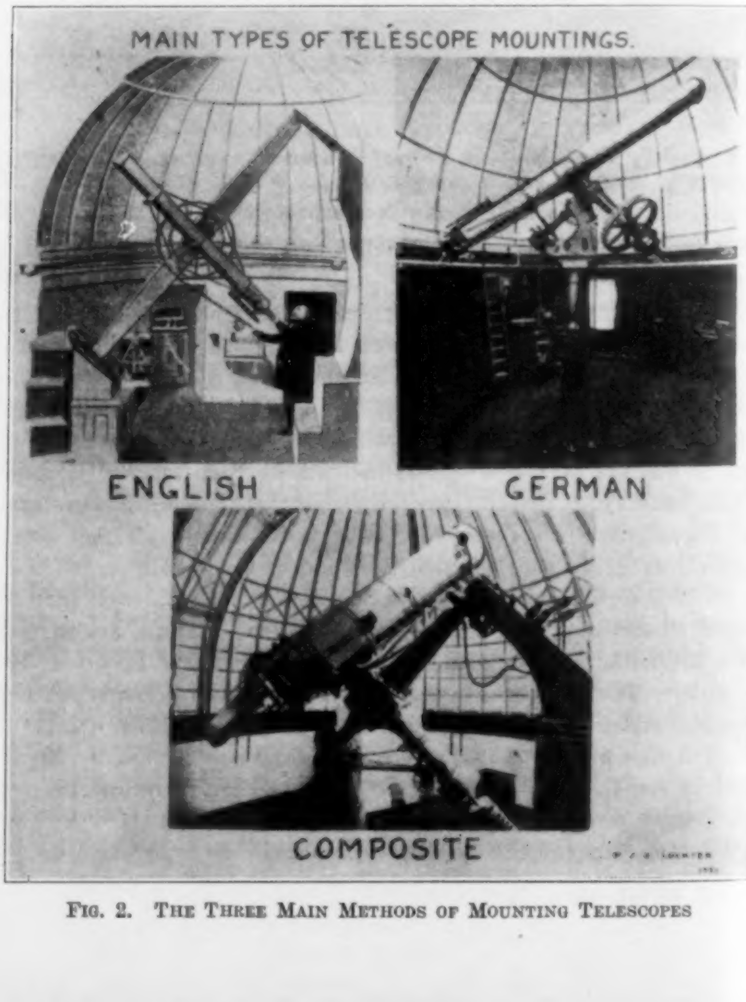


FIG. 2. THE THREE MAIN METHODS OF MOUNTING TELESCOPES

In mounting large refractors the standard forms have occasionally been departed from in order to attain some special end. These may be termed "novel" forms, and four examples may be mentioned here.

Thus, at the Paris Observatory, there was erected in 1890 a 23½-inch objective of 62 feet focal length in a tube mounted in the "Condé" form, after the design of Monsieur Loewy. This instrument is so constructed that the observer is housed in a comfortable room in which the eye end of the telescope is suitably fixed, and he can observe any object in the heavens without moving from his chair by means of reflections from two mirrors in the peculiar shaped tube after the light has passed through the object glass.

Another novel form was exhibited at the Paris Exhibition of 1900 to utilize an object glass of 49 inches aperture and 197 feet focal length made by Monsieur Gautier.

In order to avoid the necessity of having to move such a heavy object glass and tube, the principle that was adopted was to place the telescope horizontally in a true north and south position with the object glass facing north. The light from any celestial object was then reflected into this tube by means of a large silver-on-glass mirror mounted as a siderostat and moved by clockwork. This particular telescope has never been effectively used, so in spite of its great objective it has not been classed as the greatest telescope of to-day.

A curious mounting is that employed for the 27-inch telescope of 70 feet focal length of the Trepstow Observatory, near Berlin, erected in 1909. The main object in the construction was to obviate the cost of a large dome and rising floor, and also to make the eyepiece of the instrument very easy of access for numerous visitors. To accomplish this the tube was erected on the modified "German" type of mounting in such a way that the eye end of the tube should be situated just above the upper end of the polar axis. The tube was counterpoised in declination by two great weights placed at the extremities of two long arms extending northwards and symmetrically placed as regards the tube. There the eyepiece was in the center of motion of the telescope and practically stationary for all positions of the tube; also by simply setting the tube near the position of horizontality it could be covered by a light wooden low structure.

The last novel form of mounting to be mentioned was erected in 1912, and is known as the 150-foot Tower Telescope of the Mount Wilson Observatory. Its origin developed from the fact that an objective of long focal length was required to be used in conjunction with a spectroscope also of long focal length.

Previous experience had shown that air currents near the ground affected the definition when such long instruments were used in a horizontal position. Dr. Hale conceived the idea of mounting the object lens high up on a metal girder tower and throwing the images of the celestial object to be studied vertically downwards on to the spectroscope placed vertically in a shaft in the ground, employing two mirrors on the top of the object glass to reflect the object downwards. The actual lens in use has an aperture of 12 inches and a focal length of 150 feet, while the focal length of the spectroscope is 75 feet. One of the chief peculiarities of the construction was that the girder work of the tower was really in duplicate, one within the other and not touching at any place. While the dome at the top rested on the outer casing, the mirrors and lens were supported by the inner one; thus any wind pressure which might set up vibration in the outer casing did not affect the inner casing, which supported the optical parts of the arrangements.

Reference has previously been made to the various forms of reflecting telescopes, such as the Newtonian, Gregorian, Cassegrainian and Herschelian, and to the first reflector ever made—namely, that by Sir Isaac Newton in 1668.

The growth of this type of telescope will now be briefly described. For a long time the progress was slow, but the impetus was given by Sir William Herschel, who was the first to make mirrors of really large dimensions. The mirrors themselves were composed of speculum metal, an alloy of copper and tin and highly polished. Herschel's largest reflector was 4 feet in diameter with a focal length of 40 feet. It was erected at Slough, near Windsor, in the year 1789. The tube was pivoted near the ground and mounted between high wooden trestles; while there was no restriction to its movement in the vertical direction it was only capable of a very small lateral motion east and west of the meridian.

Just as Galileo with his pigmy refractor revolutionized ideas with his wonderful discoveries, so Herschel with the giant reflector of his own construction made momentous additions to our astronomical knowledge.

Nearly sixty years later (1845) Lord Rosse ground, polished and mounted a 6-feet reflector at Parsontown, in Ireland. This leviathan of 54 feet focal length was mounted somewhat after the fashion of Herschel's, only solid masonry replaced the wooden trestle structure. The movements of the tube were also similarly restricted.

While Lassel's reflectors, the largest of which was 4 feet and made in 1863, were not an advance in size, yet he instituted a great improvement by mounting the instrument equatorially, after the modified "German" type.

Grubb in 1870 completed a mirror of the same dimensions for the Melbourne Observatory, mounting it in the "composite" fashion. This was the last large reflector which employed a mirror of speculum metal, because glass mirrors were beginning to supersede them.

In the years 1856 and 1857 Steinheil and Foucault discovered a method of making mirrors by depositing silver on glass surfaces. This produced a highly efficient reflecting surface and soon came into common use. One of the first large reflectors with this type of mirror was that made by Foucault himself for the Paris Observatory. It was constructed on the Newtonian principle, mounted equatorially on a heavy wooden framework movable on castors and clock-driven.

In 1875 Martin made a 4-feet mirror for the same observatory, but it was only owing to the thinness of the glass disc in relation to its diameter that it was not a success. The completed instrument was mounted in the "composite" form.

An immense advance was made by Common, who in 1888 constructed and used a mirror of 5 feet diameter. The tube was mounted on the modified "German" plan, being placed in a fork bolted to the upper end of the polar axis. To minimize the great weight of the polar axis on its bearings the novel idea of floating it was adopted.

It was not till the year 1908, that is, twenty years later, that a mirror of the same size was made. This was accomplished by Ritchey for the Mount Wilson Observatory: the style of mounting was rather similar to that adopted by Common.

Another ten years saw the completion (1918) of the 6-feet reflector for the Dominion Observatory, Ottawa. This great glass, the work of Brashear, is equal in size to the speculum mirror of Lord Rosse, and weighs 2 tons. The form of mounting the tube is after the "composite" type, the moving parts weighing 35 tons. The telescope is capable of being used either as a "Newtonian" or as a "Cassegrainian."

It should be noted that "rising floors" in an observatory can not be employed for reflecting telescopes of the Newtonian form, because the eye end of the telescope is situated at the upper end of the tube. The staging to accommodate the observer is therefore of very complex construction, and the arrangements adopted vary very considerably from one instrument to another, no two forms being alike.

We come now to the largest reflector of the present time—namely, the Hooker 100-inch erected at the Mount Wilson Observatory in 1919. This mirror of 13 inches thickness, and weighing 4½ tons, has a focal length of 42 feet. While the block of glass was

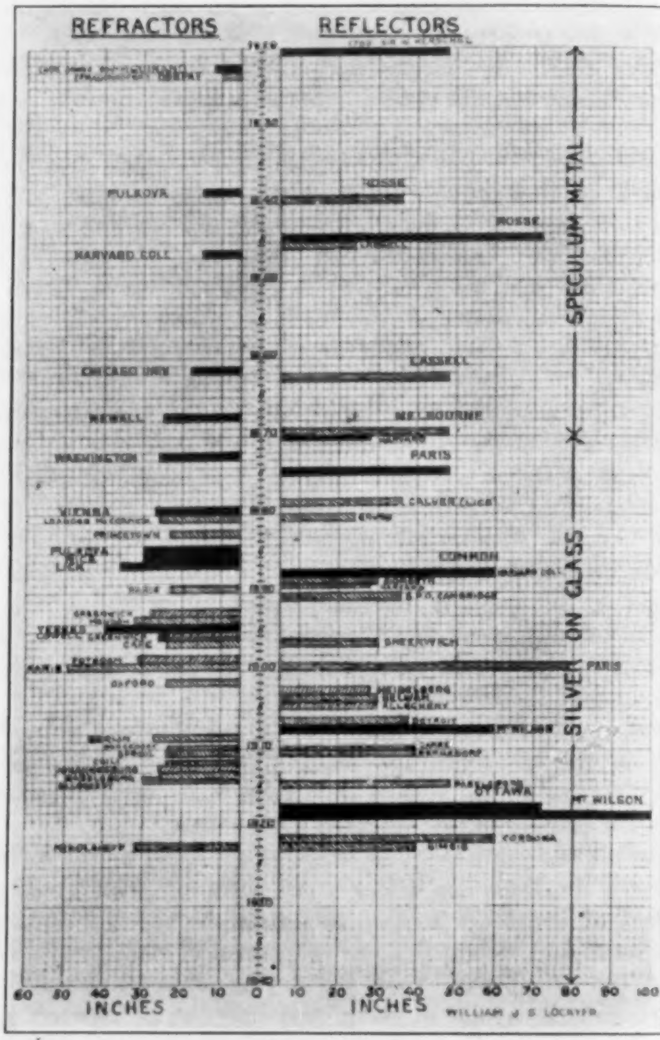


FIG. 3. APERTURES AND DATES OF LARGE TELESCOPES

cast in France, the figuring and silvering is due to the skill of Ritchey. The great tube carrying the mirror is mounted after the "English" type, and the moving parts of the telescope amount in all to 14½ tons. Either the "Newtonian" or "Cassegrainian" form of instrument can be utilized.

Thus, after a lapse of two and a half centuries, the 1-inch reflecting telescope of Sir Isaac Newton has grown into a monster of 100 inches.

Having thus separately surveyed the progress of the growth of

the two types of telescopes, it is interesting to obtain, if possible, simultaneously a bird's-eye view of this progress. This may be possibly accomplished by means of the accompanying diagram (Fig. 3).

The period of time covered is the century beginning in 1820, and while the years are displayed down the center of the diagram, the sizes (in inches) of the object glasses and mirrors are shown respectively on the left and right hand sides against the years of their erection. Many other large instruments of interest, apart from those that were records in size in their time, have been inserted.

No less interesting and important is the study of the geographical distribution of large telescopes. For this purpose the positions of the great telescopes have been indicated on a chart of the World (Fig. 4).

On this diagram refractors from 30 to 40 inches aperture are represented by large black spots, and those between 20 and 29 inches by small black dots. On the other hand, reflectors from 60 to 100 inches in diameter are indicated by large circles, and those from 30 to 59 inches by small circles. It will be seen that the very large telescopes predominate in two main regions—namely, Europe and the United States with Canada. Only one telescope of the very large type is situated in the Southern Hemisphere, and that is the 5-feet reflector for the Argentine National Observatory at Cordoba. This instrument, although completed, has not yet been erected.

South Africa and Australia are both blank in this respect, except that a 26-inch refractor is near completion for the former;

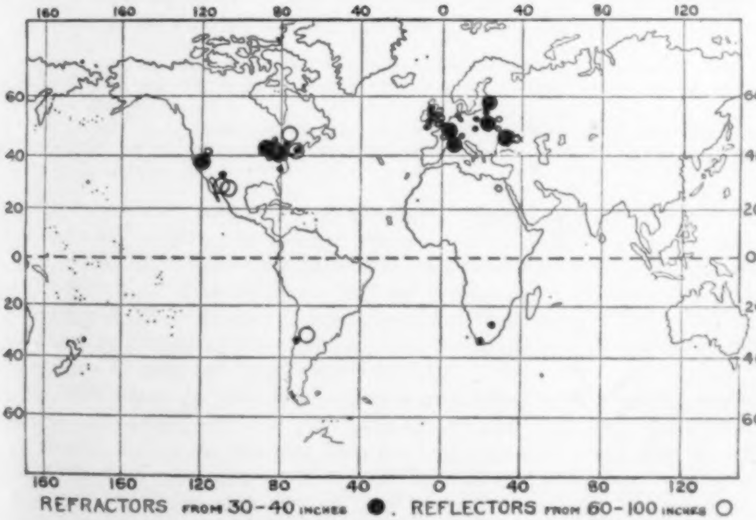


FIG. 4. GEOGRAPHICAL DISTRIBUTION OF LARGE TELESCOPES

but it is hoped that in the near future both these countries will be better represented.

The limit of size of a telescope, whether it be refractor or reflector, for the accomplishment of useful work, has by no means yet been reached, providing the instrument be placed in a specially selected locality high up on some extensive plateau where the "seeing" is of a high-class nature during the greater part of the year.

This limit is at present only temporarily restricted by the maximum limit that can be reached by those whose work it is to cast the necessary glass blocks. The mounting of even the largest telescope is now only a mild engineering problem.

It must not be forgotten, however, that large telescopes are very expensive not only to construct but to house; but experience has shown, at any rate in the United States of America, that when occasion arises there generally looms up above the horizon an enthusiastic private donor.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON
SCIENCE SERVICE, WASHINGTON

THE EVOLUTION OF THE USELESS

"What is the use of it?" was the question that used to be asked by an investigator when he found a strange structure or substance in a plant or animal.

He then set himself to finding out the use of it, and sometimes when he could not find out for sure what it was good for he invented a more or less plausible reason for its existence and peculiarities. It never occurred to him that the reason he had difficulty in getting an answer to this question might be that there was no answer to get. For if the investigator lived several generations back, in the age of the Bridgewater Treatises, he assumed that a living creature was constructed like a machine, where every part has a purpose. If he lived one generation back he assumed that all parts and peculiarities of plant or animal were developed from the accumulation of minute favorable variations and, therefore, were, or at least had been, of value to the creature in his struggle for life. This was the theory of "pure Darwinism," but we must remember that Darwin himself was not a pure Darwinian, just as Karl Marx always refused to be classed as Marxian.

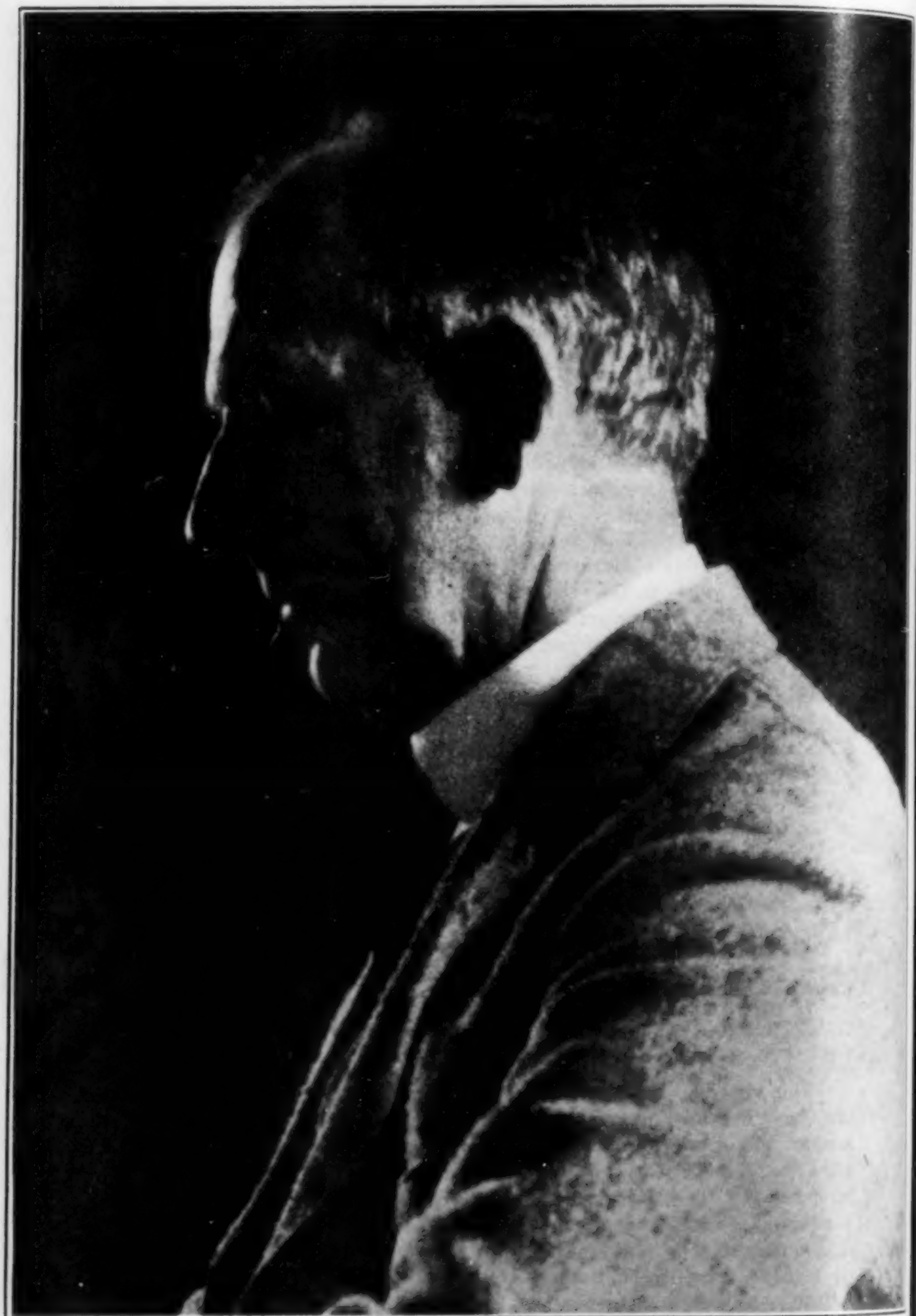
But the biologists of the present generation have given up the expectation of finding a use for everything, for they do not now assume that everything is useful in the sense of being a benefit to the creature possessing it. The characteristic under consideration may be an accidental or inevitable accompaniment of its general development. It may be a mere by-product of its life process.

This modern point of view was expressed by A. G. Tansley, president of the Botanical section of the British Association for the Advancement of Science at the recent Liverpool meeting, when he said:

> An organism may produce parts which are useless or even harmful to it, provided that the whole is still able to carry on and reproduce itself in its actual conditions of life.
>
> In regard to a multitude of characters there is not only no proof but not the smallest reason to suppose that they have now, or ever did have, any survival value at all.

This view will relieve the zoologists and botanists of a lot of the bother they have had in trying to hatch up reasons for everything. Formerly when a plant was found to contain something poisonous or bad tasting, the botanist "explained" it by assuming that the noxious compound was put there or developed there because it kept the plant from being eaten. But the compound is formed by the chemical reactions of the plant's vital processes and it may or may not be a protection to it.

So, too, when the old-school entomologist found an insect that looked hideous—to human eyes—or that gave off an odor that was disagreeable —to human noses—he assumed that the bug appeared or smelled as horrible to the birds that prey on it as it did to him, and, therefore, its enemies avoided it. Perhaps that was so—and perhaps it wasn't. A skunk undoubtedly makes use of its poison gas as a weapon of defense, and it cer-



—Photograph by Julian P. S

DR. WILLIAM WALLACE CAMPBELL

Recently installed as president of the University of California, since 1901 director of the Lick Observatory.

tainly is an offensive weapon. But many a poor bug may exude an odor quite as bad in proportion to his size and yet not get any benefit from it. Doubtless he has become so used to his odorous aura as to be quite unconscious of it, and often wonders why he is not more popular in society.

A scientist from Mars studying our earthly ant-hill would be quite puzzled to understand why the automobiles shot out jets of ill-smelling smoke until the happy thought occurred to him that it was for the purpose of preventing pedestrians approaching too close and perhaps climbing on behind. He would wonder why heaps of shale were stacked up around our coal mines. But he would consider the question solved when he surmised that they could serve as ramparts in case the mine mouth were attacked by a mob of strikers.

Man may be "the measure of all things," as Protagoras said, but he is liable to mislead himself when he attempts to put his own meaning into nature.

THE TURKEY OR THE EAGLE

Among the problems which the founders of the republic thought they had decided and disposed of, but which persist in bobbing up to perplex later generations, is the question of whether the turkey or the eagle is the more suitable as a national emblem, and hence as the visible representation of a national ideal. The vote of 1782 for the eagle did not settle the matter, and Franklin's plea in favor of the turkey comes up for more careful consideration at Thanksgiving and Christmas time. This patriotic and practical statesman objected to the adoption of the bald eagle as avian emblem of America on the grounds that:

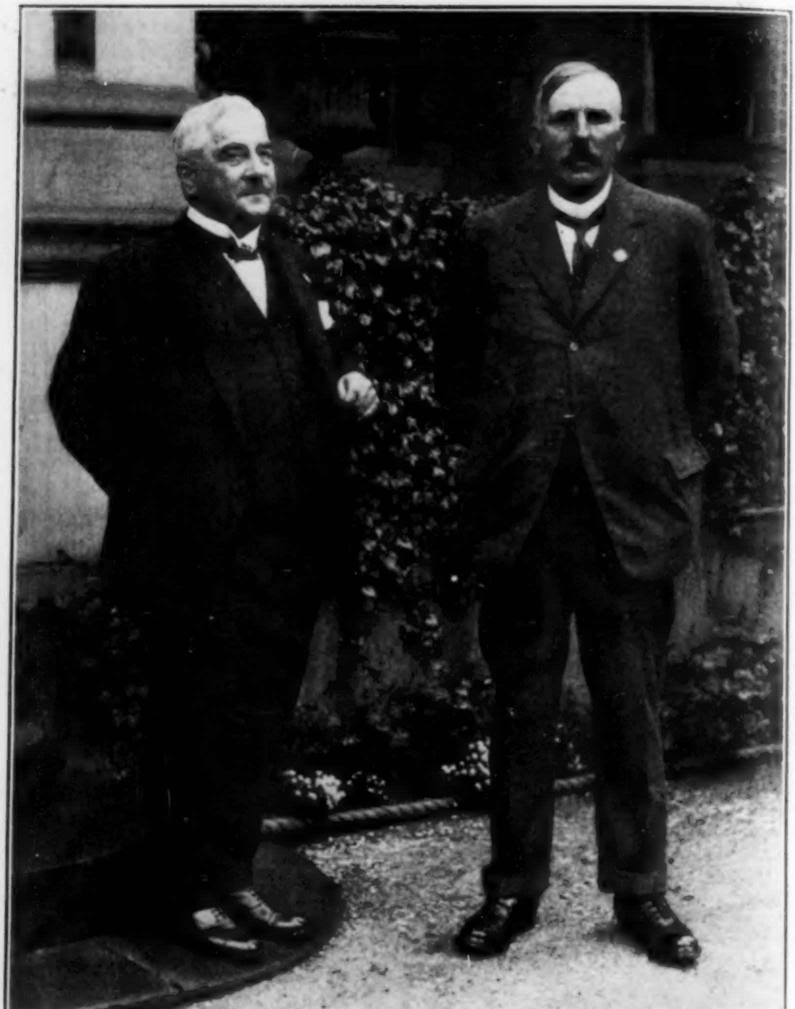
> He is a bird of bad moral character; he does not get his living honestly; you may have seen him perched on some dead tree, where, too lazy to fish for himself, he watches the labor of the fishing-hawk, and when that diligent bird has at length taken a fish and is bearing it to its nest the bald eagle pursues him and takes it from him. Besides, he is a rank coward; the little kingbird attacks him boldly. He is therefore by no means a proper emblem.

Ernest Ingersoll in his new book, "Birds in Legend, Fable and Folklore," says that a mistake was made by the designer of our national coat of arms in taking as his model the bald eagle for "none of these depreciatory things could Franklin have truly said of the skillful, self-supporting and handsome golden eagle—a Bird of Freedom indeed. Audubon named a western variety of it after General Washington. This species was regarded with extreme veneration by the native red men of this country."

The eagle was finally adopted by Congress because they were assured by the heraldry expert consulted that the eagle was "truly imperial" and quite in accord with the escutcheons of the Old World.

This, however, was to Ben Franklin an argument against the eagle rather than for it, and he nominated the turkey as an opposition candidate on the grounds that it was a native American bird, a useful and stately fowl, and not deficient in courage as is shown by the fact that it would not hesitate to attack any "Redcoat" that entered its barnyard.

Whether the turkey would be as readily aroused to the fighting pitch at the sight of modern British khaki or German feldgrau may be doubtful,



—*Wide World Photos*

SIR ERNEST RUTHERFORD AND DR. J. G. ADAMI

Sir Ernest Rutherford (standing on the right), Cavendish professor of experimental physics at the University of Cambridge, presided over the recent Liverpool meeting of the British Association for the Advancement of Science, where this photograph was taken. Dr. Adami, vice-chancellor of the University of Liverpool, was formerly professor of pathology at McGill University.

but nobody who has encountered the turkey on his home ground will question his courage in defending his rights against any invader.

The imperial eagles of Europe, whom our revered forefathers unfortunately followed, have in the last five years lost their heads as swiftly as turkeys at Thanksgiving. The Russian and Austrian, that had two heads, have lost both. Ours is about the only eagle left of the lot, although the Polish eagle has again spread its wings and manifests the old imperial spirit.

In France a similar contest of ideals and emblems is manifest throughout its history. The eagle of Caesar conquered the Gallic cock, but Chanticleer again arose with the First Republic. Napoleon the Great and Napoleon the Little brought back the empire and the eagle, but their reign was short. Just now it seems uncertain toward which ideal France will turn, toward predatory imperialism or utilitarian democracy.

All countries in all times are torn between these opposing forces and are alternately tempted to turn toward the soaring eagle or the farmyard fowl, toward the glory of militarism or a substantial family meal.

The turkey is one hundred per cent. American in spite of its foreign name. The Department of Agriculture should bring suit under the pure food law to prevent such misbranding, for it is a shame that America's only contribution to the domesticated fauna of the world should be credited to the indolent Ottoman.

But we must admit that the turkey is losing repute in his native land. The number of turkeys in the United States is now about 3,000,000. This is more than are in all the rest of the world, but less than there used to be here. Surely the fowl that saved the Pilgrim Fathers when they were in danger of dying for lack of protein is as worthy of honor as the geese that saved Rome.

SOY

THE recent rise in restaurant prices has sent economical Americans flocking to the chop sueys where a savory and satisfying meal can still be obtained for a small sum. The Chinese in their efforts to keep three million people above the starvation point for three thousand years have been forced to figure closely on food values, and, although they could not tell a calorie from a vitamin at sight, they have worked out some very ingenious dietetic schemes.

Especially have they been successful in getting along with little or no meat and milk. With us Americans meat has been the main part of the meal with vegetables on the side. With the Chinese this is reversed and meat has in many cases been reduced to a condiment. Scraps of beef or pork chopped up in the chop suey or a few shreds of chicken laid on top give the eaters the illusion of a meat dish. And by using sprouted grain they get the vitamins that are absent in our cereals.

The chief difficulty of a vegetarian diet is to get a sufficient amount and variety of proteins. Beans and peas are the richest in proteins, but they are not of the sort and proportion found in meats and needed for our muscle-making.

But there is one exception and that is the soybean. This contains no starch but carries instead from 30 to 45 per cent. of protein, and from 18 to 24 per cent. of oil. From this it will be seen that the soybean resembles

MR. RICE AND DR. CLARKE WITH HENRY'S ELECTRO-MAGNET

E. W. Rice, Jr., honorary chairman of the Board of Directors, General Electric Company, and Dr. John M. Clarke, director of the New York State Museum. Dr. Clarke is holding the little bell which in 1831, during experiments of Joseph Henry, gave forth the first sound ever heard at a distance by the use of the electro-magnet. Mr. Rice is holding the original electro-magnet. On December 17 Mr. Rice and Dr. Clarke made addresses in memory of Henry, which were transmitted by radio from coast to coast and across the Atlantic.

animal foods in being rich in fat and protein and devoid of starch. What is more remarkable, the soybean contains a dozen kinds of protein compounds that are the same as those found in milk. In fact a "vegetable milk" can be made from soybeans and from this vegetable curds and cheese. These form a large part of the diet of Chinese and Japanese who abstain from animal food either because they are Buddhists or because they are poor. By milking the soybean they can get ten times as much lacteal fluid per acre as if they pastured cows on the land. Italian physicians who used soy milk as infant food during the war report that it was better tolerated than cow's milk by some of the babies.

The soy milk products have not yet come into use with us, but the American patron of the chop suey has acquired a taste for another product of the bean, the little glass cruet of brown sauce that seasons the rice. It looks and tastes like meat extract, such as we use in making beef tea, and is really much like it in composition and nutritive value. This shoyu or soy sauce is made by long fermentation and ripening of a mixture of beans and wheat in brine. The longer the process the better the product. Six months or a year may suffice for the masses, but to suit the taste of the Oriental connoisseur it must be sunned for five years or even thirty, the jars being patiently uncovered every day and covered every night or whenever it rains. Over two million barrels of soy sauce are made in Japan every year.

The soybean was first introduced into America in 1804, but it is only within the last ten years that it has come to be commonly raised for oil and cattle food. Now it is becoming one of the major crops in various states. In Ohio at the present rate of increase soy will surpass oats in acreage ten years hence.

But American housewives are slow to admit soy foods to their table in spite of the assurances of C. V. Piper and W. J. Morse, of the Department of Agriculture, that some eighty palatable and nutritious dishes from soup to dessert can be prepared from the bean. It seems that soy will be as long in fighting its way into popular favor as were potatoes and tomatoes in their day.

THE EVAPORATION OF MAN

WHEN Hamlet expressed the despairing desire "that this too, too solid flesh would melt, thaw, and resolve itself into a dew" he did not realize that his wish was being granted even as he spoke. The louder he lamented and the hotter he got about it the more of his flesh was being resolved into a dew which besprinkled his forehead or was thrown off with his breath. Everybody is evaporating in the same way all the time even when he is not conscious of perspiring. In fact, the insensible perspiration accounts for a greater loss of water than what is seen and felt as sweat. All this is necessary to prove this is a sufficiently sensitive balance.

There was such a balance on exhibition at the Carnegie Institution in Washington some time ago. It was so strong that a man could sit in its scale pan and so sensitive that a pin's weight would tip the beam. Dr. F. G. Benedict, of the Nutrition Laboratory, who had charge of the experiment, had to keep putting on weights to make up for what the young man was losing in the way of water vapor while we watched him. Since he had on an overcoat it was evident that most of the water was given off from the lungs and not through the skin. In fact, other experiments have

shown that a man when clothed loses water by evaporation more rapidly than when nude.

Of course exercise of any sort increases the loss of water. Dr. Benedict found that a football player lost 14 pounds of his weight in a game lasting an hour and ten minutes. A marathon runner lost eight and a half pounds in a three-hour race. A varsity oarsman lost five and a half pounds in a four-mile race lasting 22 minutes. Most of this loss is perspired water, largely from the lungs, but a small fraction of it comes from body tissue burned up in the fires of life.

Even when in bed and asleep the loss of water and carbon dioxide goes on continuously. In 158 experiments on 50 different men there was an average loss of one and a third ounces per hour while lying quietly in bed. So the average adult wakes up in the morning after eight hours sleep some ten ounces lighter than when he retired. We restore the loss when we eat and drink.

From these experiments it is evident that scales accurate enough to ascertain the weight of the breath may serve as a measure of metabolism, an index of the activity of the bodily processes, in place of the more bothersome methods now in use, the determination of the heat production by the calorimeter or of the analysis of the expired air by chemical methods. The new method has already been used in hospitals where it is important to know the metabolism of the patient. Six women patients were found to lose from six to thirteen ounces each during eleven hours in bed.

Each breath of air that we inhale adds some oxygen to our bodily substance. But with each breath of air that we exhale the oxygen escapes again, carrying off with it some of the carbon and hydrogen that has served us as fuel. The food we eat keeps up our energy and the water we evaporate relieves us largely of our surplus heat. So the income and outgo of both matter and energy are kept perpetually and automatically in balance. Or if they are not, we become speedily bankrupt and finally defunct. Stopping our outgo of evaporated water would kill us quicker than stopping our income of food and drink.